MINISTRY FOR CONSERVATION
VICTORIA

Preliminary Assessment of the Effect on Flora Conservation of the Proposed Intensive Harvesting of Timber in the Otway Ranges

REPORT TO THE

ECOLOGICAL SURVEY CO-ORDINATING COMMITTEE

BY : ROSEMARY A. HOOK

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ECOLOGICAL SURVEY CO-ORDINATING COMMITTEE
OF THE MINISTRY FOR CONSERVATION

PRELIMINARY ASSESSMENT OF THE EFFECT ON FLORA CONSERVATION OF THE PROPOSED INTENSIVE HARVESTING OF TIMBER IN THE OTWAY RANGES

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This report is part of a series of reports carried out by the Ministry for Conservation to make a preliminary assessment of the effects of timber harvesting on some aspects of the environment in the Otways. It was a desk study carried out in March and April 1982 and was designed to meet the deadline of the Inter-Departmental Task Force examing intensive timber harvesting in the Otways. Although the reporting deadline for the Task Force was subsequently extended, this report was completed to meet the original deadline.

PRE-PUBLICATION COPY

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1. OBJECTIVES OF REPORT

The overall aim is to make a preliminary investigation into the effects of intensive timber harvesting on the flora of the Otway area.

The objectives, as defined in the task specification, are to:

(1) Comment on the value of the native vegetation in the area being considered for pulpwood harvesting with respect to various values, including presence of rare or unusual species or communities, ecological values and visual amenity.

(2) Provide an assessment of possible effects on the maintenance of vegetation values of application of the current forest management prescriptions for the Otway forest for the four pulpwood harvesting options described in the Preliminary Report of the Task Force.

(3) Recommend appropriate management strategies for the pulpwood harvesting areas to ensure that vegetation values are maintained.

(4) Comment on the effect of adoption of these strategies on the availability of timber for harvesting.

(5) Identify further work required to improve the knowledge of flora conservation in the Otway area.

2. FLORA CONSERVATION

The term flora conservation is usually used with the implication of maintenance of the status quo but vegetation is dynamic and constantly changing; even though the changes are relatively minor in some instances, vegetation is not static. For example, areas of vegetation which are mature now will eventually senesce and be replaced by regenerating trees. The aims and methods of flora conservation, therefore, need to be defined so that allowance is made for natural changes in the vegetation with time.

2.1 Objectives

Given below are the objectives of flora conservation:

(1) The maintenance of populations of rare, unusual and interesting plant species.

(2) Maintenance of the range of major community types, defined on the basis of both structure and floristics.

(3) Maintenance of the range of component communities within the major community types. The component communities are distinguished by one or more of the following attributes -

- species composition
- age uniformity or diversity in the dominant stratum
- maturity of the vegetation.

(4) Maintenance of an area of land where the vegetation develops in the absence of disturbance by man. Management with this aim requires that man's activities and, to as large an extent as possible, the results of man's activities, for example fire, are kept out of such areas.

The first three objectives differ from the last in that the first three aim to conserve particular vegetation types while the last has no particular vegetation type in view.

(5) Maintenance of as many areas of native vegetation as possible, even if these areas do not contain any rare species or communities. Variation within species means that maintenance of a large population results in the maintenance of the genetic variability and the ecotypes adapted to local conditions; genetic variants may be of value in the future.

2.2 Management Required

The first objective requires -

(i) the setting aside of areas of land with rare and interesting plant populations, and

(ii) management of that area of land so that those populations are able to survive.

Such management requires an understanding of the ecology of the species involved so that necessary management practices can be implemented. For example, several heath species require firing for their re-establishment, while fire needs to be excluded from Nothofagus communities.

The second and third objectives also require the setting aside of areas of land which contain the major community types. These areas need to be at least a size sufficient to contain representatives of the component communities and, allowing for the natural changes in these communities, sufficient to permit maintenance of this diversity through time. Management strategies need to be developed, particularly with respect to the use of fire, so that the diversity of component communities is retained.

Management for the fourth objective is specified within the objective. Management for the fifth objective is more difficult to prescribe since many areas on which it is desirable to maintain native vegetation have a primary function other than flora conservation. Management practices for these uses will not always be compatible with maintenance of the vegetation and so, if the land is to be used for flora conservation at all, a compromise must be reached between the optimum management of the land for the primary use and for flora conservation. The question becomes one of how much to reduce what may be optimal management for a particular use, to allow for flora conservation.

3. THE BROADER PERSPECTIVE OF THE VEGETATION - LONG TERM VEGETATION CHANGES, LAND CONSERVATION AND OTHER VEGETATION VALUES

The maintenance of community types and populations of rare and interesting species is an important aim. The place of the vegetation in the broader perspectives of time and land functioning, however, should not be overlooked. It is very easy to restrict one's vision and understanding to the present and not to consider processes which are occurring over much longer time periods and the effect on long-term processes that current management practices, including those aimed at maintaining specific vegetation types, have.

There is evidence to suggest (Singh et al, 1981, and Ashton, 1976 and 1981) that the predominance of sclerophyllous vegetation may be the result of frequent burning. This is probably at least partly the result of the sclerophyllous vegetation types having life cycles adapted to this burning frequency. It may also be due to gradual nutrient loss caused by the burning so that the nutrient reserve of the soil is unable to maintain the broad-leaved vegetation types. However, whatever the reasons for their present predominance, the long-term effect of continued frequent burning in order to maintain many of these sclerophyllous populations may be to further reduce the soil nutrient reserve, with a consequent effect on vegetation type and quality.

As well as responding to processes in the environment, vegetation also influences the processes which occur. For example, species composition and the age and the structure of vegetation will influence the hydrology of the soil - the volume of water transpired compared with the volume infiltrating down through the soil. These volumes have important implications for water supply, as well as for deterioration of particular soil types through the leaching of nutrients.

Vegetation cover also influences the degree of overland flow and sediment loss; surface soil, bare of vegetation, tends to compact after rainfall so that the volume of water moving over the surface is increased and the volume infiltrating is decreased. Overland flow

has the capacity to move soil particles and so the rate of erosion is also increased. This is particularly so as the loss of plant cover also means that there are no longer small roots present which tend to bind the soil and that there is a reduction in the resistance to water movement, giving the water flow a greater carrying capacity.

The relative amounts of nutrients in the soil, in living biomass and in litter is variable at any one site, depending on the maturity of the vegetation. Removal of plant biomass will remove nutrients from the plant/soil system with possible long-term implications for soil fertility.

The over-riding consideration in the use of land for any purpose is land conservation, that is, that the use in question is not increasing the rate of deterioration of the land. Land deterioration is regarding as the loss of capability of the land to sustain the productivity and uses it is currently able to sustain.

In addition to the importance of the vegetation in land processes, vegetation is also important in supplying timber, in honey production and in providing habitat for wildlife. It is also a major component of the natural landscape; the aesthetic qualities of an area and the emotional satisfaction derived from natural areas are dependent on the existence of relatively large tracts of native vegetation in an intact and undisturbed state.

4. DETERMINATION OF THE EFFECT OF INTENSIVE TIMBER HARVESTING ON THE VEGETATION

Due to the fact that vegetation responds to and is affected by processes in the environment, the vegetation in an area is directly determined by the way the area is managed, management involving the initiation and direction of processes.

Intensive timber harvesting is a method of land management and hence needs to be assessed in terms of the way it affects the processes influencing the vegetation.

In order to assess the effect of intensive timber harvesting on flora conservation and other values of the vegetation, an initial assessment is made of the effect on the vegetation; the likely changes in the vegetation can then be interpreted with respect to their effect on the value of the vegetation for different purposes; the effect on the value for flora conservation and landscape are part of this report.

5. INFORMATION REQUIRED TO DETERMINE THE EFFECT OF INCREASED HARVESTING OF TIMBER ON THE VEGETATION OF THE OTWAYS

5.1 Vegetation Inventory

An inventory of the present vegetation types - their floristics and structure - is required, along with a map of their distribution, to provide information on the basic vegetation resource. This inventory needs to cover the whole of the Otway region so that an assessment of the effect of woodchipping on the vegetation can be made on a regional basis.

5.1.1 Information existing from floral surveys and investigations

5.1.1.1 Reports surveyed and people contacted.

A determination of the information available from the more extensive surveys was made. References to smaller surveys or surveys which were later incorporated into the more extensive surveys were not included.

The major reports and surveys reviewed were:

- the resource maps compiled by the Forests Commission
- the land system survey carried out by the SCA in the Otway Ranges
- the Corangamite Study Area Report by the LCC
- A Floristic Check-list for the Otway Region by Beauglehole, Carr and Parsons
- The Distribution and Conservation of Vascular Plants in the Corangamite-Otway Area by Beauglehole
- the inventory of the natural resources of the Otway National Park compiled by the National Parks Service

. Mrs. Betty Duncan who, with Mrs. Golda Isaac, is carrying out a survey of Victorian ferns and fern allies, was contacted to determine whether she had collected any information relevant to the Otways area. Also contacted was Dr. R.F. Parsons from LaTrobe University.

5.1.1.2 Data obtained from these reports and contacts.

The information obtained has been summarised and included in Appendix 1.

5.1.2 Assessment of adequacy of resource information

. It appears that no vegetation surveys cover areas of private land.

. Areas of Crown land which, according to Beauglehole have not yet been adequately surveyed from the point of view of determining species content and the presence of rare, interesting or restricted species, are indicated on the accompanying map.

. Some information is available on the rarity and scientific interest of species which have already been identified.

. Descriptions of several community types and species associations in the area do exist; the most detailed of these are for the Otway National Park and included Reference Areas.

. The preliminary report by the National Parks Service on the vegetation of the Otway National Park comments on the outstanding quality of some of the closed rainforest with Nothofagus and the rarity of E. regnans growing on Tertiary sediments. Apart from this, specific information on the rarity, quality, age, or scientific interest of different communities in the Otway area is not available.

. Mapping:

(i) The National Parks Service has maps of the vegetation communities within the Reference Areas.

(ii) The 1:25 000 resource map compiled by the Forest's Commission has detailed mapping of the predominant eucalypts but information on understorey and stream vegetation is lacking. When complete, these maps will only cover the mountain forests which more or less correspond with the Tall Open Forest IV as mapped by the LCC.

(iii) The vegetation map of the LCC covers all Crown land but the mapping units are broad as structure only is used as the basis for distinguishing the different units. Six units cover almost all the area. There is some correlation between vegetation associations and structure but again the differences are at a broad scale.

5.1.3 Further information required

Further information is required on the vegetation resource before an assessment can be made of the current situation with respect to flora conservation and of the likely effects of the proposed increases in timber harvesting.

. There needs to be a survey of native vegetation on privately owned land in the Otways area to determine the community types which exist and whether these areas of land contain rare or unusual species or rare, unusual or, in some way outstanding, communities.

. The blocks of Crown land regarded by Beauglehole as being inadequately surveyed with respect to determining the presence of rare or unusual species, need to be surveyed.

- A survey of areas of native vegetation, both on Crown and private land, needs to be undertaken to determine the major community types and their components and to map their distribution. Rare communities, or those which are in some way significant, need to be identified and their locality recorded.

5.2 Processes Within the Vegetation

As well as an inventory of the vegetation resource, a knowledge of the processes occurring within the vegetation and between the vegetation and land, ie. a knowledge of how the vegetation functions, is also required. This is necessary in order to assess the effects of management practices.

An understanding of vegetation/land functioning requires a knowledge of a broad range of processes and it is impossible to summarise these here. Instead, aspects of vegetation processes are commented on in relation to specific management practices; this has been included in Appendix 3.

5.3 Management Objectives, Strategies and Prescriptions

5.3.1 Definitions

The objectives of land management define what the management of a given area of land aims to achieve. Management strategies and prescriptions define the ways in which it is intended to achieve the specified objectives; strategies outline the broad directions for land management, while prescriptions define the way particular practices will be carried out.

5.3.2 Overall management objectives and strategies

The Land Conservation Council has made recommendations for the use of Crown land within the Otway area and who the managing authorities should be (see Final Recommendations, Corangamite Area,

LCC 1978). These recommendations represent an overall management strategy for the area. The broad objectives of land management in the Otways on which this strategy is based have not been clearly set out or defined although some of them are contained in the preamble given under each land use. Specific objectives for different land uses and recommended management strategies to achieve these specific objectives are also given in some instances.

5.3.3 Current management objectives, strategies and prescriptions for the areas of Crown land

Knowledge of these is required in order to assess the likely effects of the different types of land use on the vegetation. If the assessment is to be on a regional basis, it is necessary to examine the management objectives, strategies and prescriptions for all areas of Crown land, not just those proposed for pulpwood. Time limiations have prevented this; only strategies, objectives and prescriptions covering most of the larger areas of Crown land have been reviewed and are summarised in Appendix 2.

5.3.4 Management objectives, strategies and prescriptions for proposed pulpwood operations

The objective of the proposals to increase the intensity of pulpwood harvesting is to obtain 70,000 tonnes or more of pulpwood per annum.

5.3.4.1 Proposed pulpwood options

The major options in broad management strategy for an extension of pulpwood harvesting were set out in the Preliminary Report of the Task Force, and are as follows:

(1) Pulpwood harvesting continues to be integrated with the existing sawlog operation, the chips being processed domestically. The quantity harvested will vary up to approximately 70,000 tonnes, depending on the availability of markets.

(2) As in (1) but with pulpwood exported from probably Melbourne or Geelong. Other substantial sources of pulpwood would be required for an economically sized operation.

(3) Maintaining sawlog production at 50,000 m^3 per annum and increasing pulpwood production by one or more of the following operations:

(i) rehabilitation of cutover and/or fire damaged forests

(ii) reforestation of cleared and partly cleared areas

(iii) cutting pulpwood in forests where there are currently few, if any, sawlogs.

(4) Increasing the production of pulpwood at the expense of sawlog production.

5.3.4.2 Detailed management strategies and prescriptions

Detailed management strategies and prescriptions have not been developed for any of the pulpwood harvesting options. Such strategies would provide information on -

- the approximate area to be harvested per annum
- the tree species to be harvested
- the minimum size of timber which can be harvested
- the areas in which harvesting is not permitted due to environmental considerations, including scenic attraction, flora and fauna, erosion hazard, etc. Some guide to possible strategies in this respect can be obtained from present management prescriptions. (See Appendix 2)
- maximum coup sizes (sizes allowed in water supply catchments for current sawlog and pulpwood operations can be obtained from Appendix 2)
- regeneration methods

- stand management practices including program for fuel reduction burning
- assuming clear felling, the minimum rotation interval.

6. THE CURRENT SITUATION WITH RESPECT TO VEGETATION AND FLORA CONSERVATION

6.1 Adequacy of Existing Reserves

6.1.1 Rare, unusual and interesting plant species

A number of rare, unusual and/or scientifically interesting plant species have been identified from areas of land already surveyed in the Otways. (See Table A1.2, and Beauglehole, 1980). Where the localities of those which have not been included in a reserve are known, they have been marked on the map accompanying the report. Nine of these occur on uncommitted Crown land, seven on Crown land designated for forest production, and three on both. Until the remainder of the Crown land is surveyed adequately (see section 5.1.2) so that the species occurring in these areas are known, a final determination as to whether all rare, unusual and interesting species occur within a reserve cannot be made.

6.1.2 Major community types

Until the major community types have been identified on the basis of species composition as well as structure in all areas, it is not possible to evaluate whether all major types are present in existing reserves.

6.1.3 Component communities

It is not possible to assess the adequacy of existing reserves with respect to covering the range of component community types until all communities have been adequately surveyed.

6.1.4 Areas where human activity is excluded

There are eight Reference Areas within the Otways where the aim is to 'ensure that these areas are maintained in perpetuity in a relatively undisturbed state and that natural processes are allowed to continue'.

These areas are relatively small so that only a limited number of vegetation types would be represented in such reserves and only a small fraction of those vegetation types represented would be included.

6.2 Effect of Current Management Strategies on the Vegetation

6.2.1 Otway National Park

A plan of management for this National Park has yet to be approved; the following discussion is based on the proposed objectives and prescriptions so that evaluations made cannot be regarded as final.

Given that one of the basic management concepts for the park is protection and maintenance of its important natural values, the vegetation of the National Park should remain in a relatively diverse and good condition.

Until the prescriptions to be developed with the FCV for fire protection are drawn up, it is not possible to comment on their effect on the vegetation. The necessary objectives of protecting park users and adjacent property from fire may mean, however, that the effect of fire on the vegetation is of secondary importance in some instances. On the other hand, the fact that the role that fire plays in maintaining heath vegetation is to be investigated, indicates that some attention will be given to the use of fire with respect to the vegetation.

Grazing and hardwood production, allowed in the National Park until 1984 and 1988 respectively, will have some effect on the vegetation. The degree of impact of timber harvesting cannot be evaluated until logging schedules are drawn up between the FCV and National Parks. One assumes, however, that areas with important species and communities will be avoided, that disturbance will be at a minimum and that every effort will be made to ensure regeneration of species in keeping with maintaining the land, floral and faunal values of the park.

6.2.2 State Parks

6.2.2.1 Angahook-Lorne State Park

Lack of a detailed inventory of plant species and communities means that it is not possible to draw up management prescriptions aimed at maintaining those which are in some way significant. Development of facilities such as camp sites and fuel reduction burning may inadvertently destroy, or lead to the deterioration of, some botanically significant areas.

Fuel reduction burning will have a strong effect on the composition of the understorey through the differences in fire response of the species present.

The effect of fuel reduction and regeneration burning on the rate of nutrient loss and the effect of this on soil nutrient reserves and on vegetation, cannot be estimated at this stage. Long term changes are involved.

6.2.2.2 Carlisle State Park

Although there is no detailed vegetation inventory or management strategy, lack of provision of facilities for the public probably means that the likelihood of vegetation destruction and deterioration is low. The effect on the vegetation of fuel reduction burning at relatively frequent intervals needs to be investigated.

6.2.3 Hardwood forests

As pointed out in Appendix 2, no comprehensive set of objectives and associated management strategies seems to have been drawn up for the Otway forests. Management strategies and prescriptions which are available require the maintenance of selected trees for animal habitat and the protection of certain areas of vegetation from logging and logging effects. These areas are on steep slopes and along stream channels; their function is to prevent erosion and to stop sediment from reaching the streams. Although such

areas also allow the conservation of flora, no reference to management specifically for flora conservation is made.

Since timber harvesting is a form of land management, it will affect many of the processes occurring within and between the vegetation and the land; the effects of interference with these processes may not always be desirable, for example, an increased rate of soil deterioration may result. If the possible undesirable consequences of timber harvesting are to be avoided, it is necessar to understand the processes which are occurring naturally, the way that management practices interfere with these processes, and the way that the vegetation/land responds. Only then is there a basis for designing management practices so that no undesirable processes are initiated.

In the absence of a detailed analysis of the problems which may arise and of a satisfactory mechanism for the development and implementation of appropriate management strategies, there is a risk that current timber harvesting in the Otways will produce significant undesirable effects. Such effects may include:

. loss (on lands which are logged) of areas containing botanically significant species or communities due either to timber removal and regeneration burning or to deterioration of such areas through fuel reduction burning, access track construction, etc.

. in the foothill forests, the development within individual coups of even-aged stands of vegetation through clear-felling and regeneration burning may seriously reduce the diversity and availability of ecological niches for both flora and fauna species. The size of any such individual area will depend on coup size.

. lack of development of old stands of vegetation due to the shortness of rotation times employed in timber production. This is of particular concern in that it greatly restricts the availability of suitable nesting sites for a range of birds and animals as well as preventing development of plant communities characteristic of the oldest type of forest.

Areas set aside from production as buffer strips along streams and on steep slopes have the potential for acting as vegetation reserves and for providing uneven-aged and mature stands. However, unless they are managed for these purposes, the quality of the vegetation they contain may be reduced by:

- regeneration burns which escape into these areas
- fuel reduction burns if these are carried out within the forest
- exposure due to removal of the surrounding forest
- the establishment of exotic species which have come in with the opening of the forest

. limited plant re-establishment on compacted soils, particularly at log loadings

. alteration of the nutrient cycle. Although loss of nutrients is known to occur through timber harvesting (see Appendix 3) and regeneration or fuel reduction burns, it is not possible to assess the significance of the loss due to lack of knowledge of:

- the magnitude of the losses in the Otway forests
- the levels of nutrients below which decreases in productivity will occur
- the accessible available and immobilised nutrient reserves in the soils in the Otways. (The estimates of soil nutrient reserves in Appendix 3 are only an approximation and cover relatively few soil and forest types.)
- the rate of input of nutrients from the atmosphere and from immobilised soil reserves compared with the rate of output of nutrients through leaching, burning, erosion and timber removal
- the rate at which nutrients become available compared with the rate of requirement by the vegetation. This is important since, although total nutrient reserves

may be adequate to supply several rotations and although the mass of nutrients released during the rotation interval may equal or be greater than the total mass required by the vegetation during the rotation span, the rate of supply of one or more nutrients at any one time may be limiting. This is particularly likely at the point of crown closure when nutrient demand is apparently greatest.

Despite these limitations, the following comments can be made:

- it would seem that, in the area of Redwater Creek where the E. regnans and associated forests are obtaining nutrient supplies from the Cretaceous sediments below the Tertiary sands, return of nutrients from the biomass to the surface soil may be critical in maintaining soil nutrient reserves of sufficient size to support the present vegetation types

- some of the soils in the Otways contain insufficient reserves of Ca or available P to supply the masses of these nutrients found in the E. regnans and E. obliqua forests of the Dividing Range studied by Attiwill and Feller (see Tables A3.4 and A3.6). In such instances, the rate of nutrient input from other sources would be critical

- with clearfelling, slash burning and heavy hand seeding, regrowth is probably denser and more uniform than under natural or selective logging conditions. The total nutrient demand is therefore probably not only greater but also less uniformly spread with time; this would exacerbate any deficiency associated with the rate of supply.

6.2.4 Other areas of Crown land

Uses of Crown land for which management strategies have not been reviewed include Reference Areas other than those in the National Park, Flora and Fauna Reserves, Bushland Reserves, Educational Areas, roadside verges, stream frontages, uncommitted areas and a number of other small categories.

Except for the Reference Areas and Flora and Fauna Reserves, these areas do not necessarily contain particularly significant species and communities, but they are nevertheless important for flora conservation. As was discussed in Section 2, it is desirable to maintain as large populations of plant species as possible so as to maintain the genetic diversity within that population; all areas of native vegetation are important for this purpose.

Timbered areas are also important due to the other values of the vegetation, ie. its role in what may be termed land functioning, the provision of habitat for wildlife and the provision of aesthetic values and the experience of 'naturalness'. It is therefore necessary to maintain timbered areas on Crown land for these reasons as well.

As it has not been possible to obtain and review the management strategies applicable to these other areas of Crown land, and as all these areas have not been adequately surveyed, it is not possible to evaluate the nature and status of the vegetation they contain. It is known, however, that some rare and interesting species do occur in the Bushland Reserves, Educational Areas and on uncommitted Crown land. (Beauglehole, 1980)

6.3 Private Property

The type and quality of vegetation growing on private property is unknown. The vegetation on private property, however, may be managed as the landowner desires, subject to a permit from the local Shire, and so deterioration of whatever is there may result from clearing, burning or other uses.

7. ASSESSMENT OF THE EFFECT OF PROPOSED INCREASES IN TIMBER HARVESTING ON THE VEGETATION AND ITS VALUES IN THE TIMBER HARVESTING AREAS

The increases in timber production considered are in addition to the current sawlog production of 50,000 m^3 per annum. The options listed are those given in the Preliminary Report of the Task Force.

The effect of changes to the vegetation on its value for wildlife, catchment purposes or prevention of erosion are dealt with in other reports.

7.1 Option One - Pulpwood Harvesting Integrated with the Existing Sawlog Operations

Provided that existing harvesting prescriptions are adhered to, so that the areas left unharvested on steep slopes and in buffer strips along streams remain the same as for current logging operations, the major effect of this option on the vegetation will be that cuased by the increased removal of logs from the site; the major implications of this are in nutrient cycling. There will also be increased trafficking which will result in increased soil compaction, affecting, in particular, soil structure. This will influence the ability of plants to establish, partly through the alteration of site drainage associated with structure decline.

As the effect on nutrient cycling of the current intensity of timber harvesting cannot be accurately assessed, it is not possible to evaluate in detail the effect of the proposed increase in intensity. The following general comments can, however, be made:

- in current harvesting operations, trees unsuitable for logging are left standing or are felled but are not removed from the site; either way, the nutrients in the stemwood of these trees remain at the site. Even with regeneration burning, nutrients within the stemwood will remain as these logs are too large to burn. Stemwood

contains variable proportions of the different nutrients within the tree (see Table A3.2); however, stemwood of E. regnans at 38 years has been found to contain 70% of the potassium and 46% of the magnesium within the tree; stemwood of E. obliqua at 50 years contained 43% of the phosphorus. Increased loss of stemwood with such nutrient reserves may be significant, particularly as nutrients within the other components of the tree and above ground biomass may be lost in smoke or by leaching and erosion during regeneration and, if they are carried out, fuel reduction burns.

- increased removals could affect nutrient balances. For example, complete removal of stemwood results in removal of approximately 63% of the above ground nutrient store of potassium but only 15% of the calcium. Inputs of calcium in precipitation also seem to be greater than inputs of potassium, so it is possible to see how the proportion of potassium relative to calcium may change.

  (Note: It has been assumed that adoption of this option will not result in areas of land being harvested which would not have been harvested prior to adoption of this option. Increases in area harvested are discussed with respect to Option Three.)

7.2 Option Two - Integration with Sawlogging but Pulpwood to be Exported

The effect of this option on vegetation in the Otways would be the same as for Option One; there would of course be implications for the vegetation in the area(s) from which the other substantial sources of pulpwood were obtained. Harvesting from private forests in the Otways could have implications for water quality, erosion and scenic values unless adequate control is possible.

7.3 Option Three - Increasing Pulpwood Production to a Level Beyond that Sustainable by Integration with the Existing Sawlog Operations Alone

7.3.1 Increased pulpwood from reforestation of cleared and partly cleared areas

Reforestation of cleared or partly cleared areas is likely to increase the populations of native plants. The undesirable impact of this option will be the removal of nutrients when the forest is harvested and the effect that this has on nutrient reserves. This is a long term effect which, with present levels of knowledge, can not be evaluated at this stage. This loss needs to be compared with the loss of nutrients which may be occurring due to increased infiltration as a result of clearing. Increased trafficking, with consequent soil compaction and structure decline, may also have some effect on the vegetation, though possibly only in the long term. The rate of recovery of the soil from these effects is not known.

7.3.2 Rehabilitation of cutover and/or fire damaged forests

The effects of this option are the result of:

(i) removal of timber and regeneration burning

(ii) the regeneration of dense, possibly single species stands in the mountain forest areas, and

(iii) future harvesting of sawlogs, pulpwood or both, in an area where these processes would not otherwise occur.

The degree of effect of removal of timber, regeneration burning and the development of even-aged, possibly single species stands of timber depends on the individual sites. Some of these cutover and fire damaged forests have the potential for providing a more diverse understorey (compared with the regenerated situation), and of providing structural diversity to the forest. Such areas

may also contain interesting or unusual species which could be lost with clearing and burning. The harvesting of sawlogs and pulpwood will increase trafficking and soil compaction and the rate of removal of nutrients; the difficulties associated with assessing the significance of nutrient removal have already been discussed.

7.3.3 Cutting pulpwood in forests where there are currently few, if any, sawlogs

The effects of this option are basically the same as those discussed in section 7.3.2. Clearing and regeneration of forests where there are currently few, if any, sawlogs could have a marked effect on the species composition and structural diversity of the forests. Structural diversity has an effect on the aesthetic appeal of forests, reduced diversity being less appealing.

7.4 Option Four - Increasing the Production of Pulpwood at the Expense of Sawlog Production

Provided the areas harvested remain the same as would be harvested for sawlog production only, then the effects of this option on the vegetation are those which result from any increased removal of timber at a site due to the reduced quality of the timber which may be harvested for pulpwood compared with for sawlogs. These effects have been discussed in section 7.1.

8. FURTHER WORK NEEDED TO IMPROVE FLORA CONSERVATION IN THE OTWAYS

8.1 Definition of Objectives and Management Strategies

In attempting to understand the situation with respect to flora conservation in the Otways, a number of problems surfaced.

. Although the LCC recommendations specify some management strategies, they do not clearly define the objectives which they are aiming to achieve with respect to flora conservation. To use the term 'flora conservation' as an objective for land management is, itself, saying little as it can be interpreted in a number of different ways with respect to extent, both in area and in population/community types.

. The LCC recommendations give no guide to the level of management for flora conservation in areas where flora conservation is a major secondary objective of management of the Hardwood Production Zone and where the management strategies for these uses may conflict.

. No mention is made in the LCC recommendations of the need to maintain the capability of the land to sustain the uses and level of productivity it is currently able to sustain.

It would seem desirable that the objectives for 'flora conservation' be defined and strategies for achieving these objectives drawn up. Such strategies would provide guidelines as to the level of management.

It would also be desirable that one of the overall strategies be that the authorities responsible for the management of Crown land in the Otways be required to define management objectives and the strategies to achieve these objectives for the land for which they are responsible. Not only does this allow assessment of the adequacy of the objectives but also provides a basis on which to assess the effectiveness of the strategies and management prescriptions.

Further Information Required on the Vegetation Resource

8.2.1 Survey information

Data and work still required on the vegetation resource include:

- detailed floristic information for all areas of unsurveyed land, both public and private

- mapping of the main community types in terms of floristics and structure

- determination of the components of these major communities in terms of floristics, structure and age and mapping of their distribution.

8.2.2 Process information

8.2.2.1 Monitoring of vegetation

The structure and floristic composition of the vegetation in selected areas need to be monitored to determine the changes that are occurring and, if possible, the factors responsible for them.

8.2.2.2 Studies on the requirements of species and communities

Much more information is needed on the requirements of species and communities, particularly in relation to burning and on the effects on them of particular management strategies. This information is essential for the formulation of management strategies that will ensure management of the land in such a way as to maintain the desired vegetation populations. Long term studies are required.

8.2.2.3 Nutrient cycling studies

Much of the paucity of information with respect to the impact of timber harvesting on nutrient cycling relates to the deficiency in our understanding of many of the processes involved and to the fact that the appropriate methodologies for investigating many problems have not yet been developed. Many of the gaps in our knowledge of the effect of intensive timber harvesting on nutrient cycling in the Otways will only be filled when scientific progress is made in these areas; benefits from such progress are not specific to the Otways.

As well as these general deficiences, however, there is also a lack of information relating specifically to the Otways; such information includes nutrient contents of the biomass, the size of soil nutrient reserve and the rates of nutrient input and output in the undisturbed forest. Dr. Attiwill from Melbourne University or members of the Forestry Department at the ANU, who are involved with aspects of nutrient cycling, could advise on the desirability of such studies and on the methods which they should employ.

8.2.2.4 Other

The above list is not exhaustive and other individuals may be aware of information which is required.

9. MANAGEMENT STRATEGIES DESIRABLE FOR INCREASED TIMBER HARVESTING SO AS TO ENSURE MAINTENANCE OF VEGETATION VALUES

9.1 General Management Principles

Since the hardwood forests are required to fulfil several functions in addition to timber production, including provision of landscape value, flora and fauna conservation and water production, management must consider these different uses. As indicated in Appendix 3, management for different uses requires that a compromise in management for any one use must be reached, although the degree of compromise for the different uses is likely to be a difficult as well as a contentious issue.

The compromise may be reached by subdividing the area to be managed into separate units, each of which is managed for optimum productivity for one use, or by managing the whole area for more than one use so that productivity for each use is reduced to a level below that which would occur were management to be for that use alone, or by a combination of both. Some land uses have similar management requirements, in which case they can be allocated to the same areas without much reduction in optimum productivity for either use.

It is essential that any compromises which must be made in relation:

- to utilising various areas for particular purposes; and
- to management practices to be implemented where several uses occur together,

be made on a rational and planned basis rather than in an *ad hoc* fashion.

This may be done by assessing the characteristics of each area (emphasising in particular the types of resource present and their quality and abundance) as a basis for evaluating the capability of each area to support various uses and the most appropriate management strategies and practices to employ. From this, the most suitable use(s) for different areas can be distinguished and compromises on management practices can be made when necessary.

The MMBW case study (1979), devised to show the likely hydrologic effects of different timber harvesting management strategies, demonstrates some of the above principles.

In their case study area, land was excluded from harvesting on the basis of:

. erosion hazard

. stream protection and other water supply values

. ridge protection

. scientific and reference areas

. recreation value

. visual amenity.

A map was then produced showing these areas along with the forest types suitable and unsuitable for harvesting. Except for slope values, the criteria used to determine whether land should be excluded from harvesting for one of the above reasons have not been given so the adequacy of the above exclusions cannot be assessed.

The study has recognised that numerous logging options are available due to the different combinations of rotation length

and harvesting and regeneration methods such as no logging and natural regeneration, thinning, selective logging or clear-felling with heavy regeneration. They selected a number of options and examined the effect of the different options on water quality and quantity and timber yields. The study points out some of the problems in determining the appropriate management strategy to be adopted but the important feature is that it allows decisions to be made with a knowledge of both the likely effects and of the limitations in understanding which may require further research in the future.

It is desirable that management of hardwood forests be planned along similar lines.

9.2 Criteria to be Considered with Respect to Management of the Forests for Flora Conservation and Landscape Value

As already discussed, development of a management plan for conflicting land uses ideally has, as one of its initial phases, an assessment of the value of the area for each use and of the desirable management strategies for that use. Given below are some of the criteria and management strategies which need to be considered when assessing the value of the vegetation of the Otway hardwood forests for flora conservation and landscape value; its values for other purposes such as habitat are being considered in other reports.

. The botanical significance, ie. the quality, rarity and scientific interest, of the vegetation needs to be assessed and areas containing communities or populations that are botanically significant at a regional level need to be set aside with a reasonably wide buffer strip to protect them from harvesting and managed so

as to ensure their maintenance. Such management includes the use of a fire regime appropriate to the community.

. Diversity of the total forest area, with respect to species composition, stand ages and stand structure, needs to be maintained. Although clearfelling and regeneration may create greater variation in stand ages and less uniform distribution of these various stands across coups within the forest, this is only applicable to ages within the rotation interval. Since this is generally much shorter than the natural life span of the forest, there is a lack of, in forestry terminology, over-mature stands. Such stands usually have high habitat, landscape and aesthetic values as well as being of interest botanically.

There is also the likelihood that, in the absence of appropriate management, the species composition of the forest may become more uniform. Although not removed in harvesting, many species may not be tolerant of other forest practices including the fire regimes used to protect and regenerate the timber resource. Such species will therefore gradually be lost.

Similarly, clearfelling practices will result in a decline in diversity of structure within communities, particularly in the foothill forests.

To reduce the extent of uniformity in the forest as a whole:

- clearfelled areas need to be interspersed with areas on which timber is left standing so that the clearfelled areas are relatively small. Vegetation left on steep slopes and adjacent to minor streams may be sufficient in steep and heavily dissected country to provide the necessary diversity.

- care needs to be taken to ensure that areas set aside from harvesting are also protected from any fuel reduction and regeneration burns; the only fire in such areas should be that needed to maintain the community in the desired condition.

- the need for fuel reduction burns should be assessed. Burns should be used as infrequently as possible and the effect on the vegetation should be taken into consideration in planning and carrying them out.

. Maintenance of aesthetic values is also dependent on the maintenance of forest diversity, so that the above strategies with respect to flora conservation will also benefit aesthetic values.

Areas of clearfelled land, particularly large areas, are unattractive and are not desirable in an area that has important tourist potential. Particular attention should therefore be given to the visual corridors, at least along the major tourist roads. Clearfelling needs to be excluded from these corridors and from any distant slopes visible from these roads. In some instances, forests could be regenerated close to the roads so as to reduce the size of the visual corridor.

9.3 Reassessment of Management Strategies

There needs to be provision for the reassessment and replanning of strategies in the light of new information, including assessment of the effectiveness of strategies to achieve the objectives.

10. CONCLUSIONS

The LCC has recommended that the Otways hardwood forests be managed with due regard for landscape and water production values and that major secondary uses include flora and fauna conservation. The vegetation is a primary factor in all these uses and values. It is therefore essential that this resource and the way it functions be understood if the area is to be managed adequately for the above values and uses and if the land's productivity for all uses is to be maintained in perpetuity.

It would seem that at present there are important deficiencies in this understanding, particularly with respect to the significance of nutrient loss through the various forest practices. Since forest productivity and hence, forest values, are dependent on nutrient supply, the long term implications of frequent nutrient removal in fuel reduction burning and periodic removal in harvesting and regeneration burning could be important.

In view of the fact that the hardwood production forests are required to also be used for other purposes, current forest planning and management gives insufficient regard to these other uses. Similarly, there seems to be no assessment of the effects of the increase in pulpwood harvesting on these other values. Indeed, much of the basic data required to manage these forests adequately and necessary for an assessment of the effect of the pulpwood harvesting proposals (for example, the total area to be logged per annum, the ecological characteristics of the forests to be harvested, the rotation interval and the length of time over which intensive harvesting is to be continued) are lacking.

While it is recognised that decisions must often be made in the absence of all facts, it is felt that the decisions made should be in keeping with the level of available knowledge. It is this author's assessment that the risks associated with the proposed increase in intensity of forest harvesting are sufficient to warrant delaying any decision with respect to such increases until an adequate information base has been

generated and evaluated. A minimal requirement is completion of a vegetation community survey over all public and private land to enable the regional importance of communities to be harvested to be assessed. Surveys of species present in areas identified by Beauglehole as inadequately surveyed (map attached) are also required.

There is also a need to examine more closely the effects of current forest management practices on the flora of the hardwood production forests with the aim of determining -

(i) the changes in floristic composition and structure being brought about, and

(ii) the forest management practices which could be introduced which would improve the floristic quality of the forests without causing large reductions in timber yields. This would involve some longer term studies. The need and urgency for these studies is increased if an increased intensity of harvesting is to be imposed.

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SUMMARY OF DATA FROM INDIVIDUAL REPORTS

1. Forest Commission Resource Maps

The Forests Commission has three sets of maps, at different scales, covering all or part of the Crown land in the Otways area.

1.1 Scale 1" : 1 mile (1:63 360)

The vegetation categories are very broad and are:

(i) Mountain Forest
- Ash regrowth
- Other

(ii) Foothill Forest (productive sawlogs < 40 m)
- Potential height : 28 m - 40 m
- Potential height : 15 m - 28 m

(iii) Unproductive Forest (sawlogs < 15 m)
- Lowlands
- Coastal scrub
- Coastal forest

(iv) Conifer Plantation

1.2 Scale 1" : 20 chains (1:15 840)

. Most of these maps were compiled in the 1950s on the basis of field traverses.

. They show greater detail than 1" to 1 mile maps; the degree of detail was exemplified on one of the maps in the Mount Sabine area on which was mapped pure stands or mixed forests of:

E. regnans
E. obliqua
E. goniocalyx
E. globulus/E. viminalis
Scrub

. The boundaries on these maps are not precise but give an approximation of distribution. River and creek vegetation is not mapped separately, nor are small changes in vegetation type. These maps are confined to the mountain forest areas on Crown land designated on the 1" to 1 mile maps.

1.3 Scale 1:25 000

. These maps, when completed, will also cover only the Mountain Forest areas on Crown land, designated on the 1" to 1 mile maps.

. They will be the most up-to-date and most detailed, being the basis for determining the aerial extent of the forest types, a prerequisite for determining the quantity of harvestable timber available.

. The information for these maps comes from large scale coloured air photographs, from data from the field traverses used to compile the 1" to 20 chain maps and from recent field checks.

. There are two series of maps at this scale:

(i) Forest type.

There is a high degree of detail, with stream vegetation and other pockets of different vegetation types being shown.

The vegetation types shown are:

E. regnans

E. regnans and *E. obliqua*

E. regnans, *E. obliqua*, *E. cypellocarpa*, *E. viminalis*, *E. brookerana*

E. obliqua

E. obliqua, *E. cypellocarpa*, *E. viminalis*, *E. brookerana*, *E. globulus*

Non-eucalypt and gully vegetation

Regeneration - *E. regnans*, *E. obliqua*, *E. cypellocarpa*

Foothill Forest

(ii) Stand classes

These maps have the same level of detail as the forest type maps. The classes mapped are:

regeneration (post 1939 origin)

regrowth (mainly 1919 and 1939 origin)

regrowth (mainly 1919 and 1939 origin) with mature and over-mature overstorey

mature and over-mature

unstocked (including scrub and gully vegetation)

foothill forest (unclassified)

A portion of the completed maps from each series is included to show the level of detail. (See Maps A1.1 and A1.2).

. So far only one map in each series has been completed. It is expected that completion of the remaining maps will take approximately another two years.

. Where and when mapping in non-Mountain Forest Areas occurs will depend on priorities and proposals for the forests.

2. SCA Land System Survey

The native vegetation in the Otway Ranges is discussed, and the structural communities and predominant species for each land system are given in the land system tables. A land system map at 1:250 000 scale accompanies the report.

2.1 Discussion on native vegetation

- This lists the different vegetation structures and the predominant and associated species found within the study area. Those categories relevant to the area covered by this report have been combined with those given in other reports in summary form in Table A1.1.

- A brief description is given of the environmental features (for example bedrock type, maximum rainfall and drainage), characteristic for each structural form and predominant species type.

- Unusual features relating to the vegetation have been noted. Those of relevance to the area covered by this report have been summarised in Table A1.2, along with similar data from other sources.

2.2 Land system tables

- It is not possible to obtain detailed information on the vegetation from these tables. However, it is possible to obtain a general pattern of the distribution of the predominant species and the relationship between predominant species distribution and environmental features.

2.3 Other information

- Nutrient data and other information on physical and chemical properties of the soil are available for a limited number of sampling sites.

3. Corangamite Study Area Report

3.1 General text

. Structural categories and associated species are described. These are given in Table A1.1 along with similar data from other reports.

. Plants of particular interest in the study area have been described. Those included in the area of interest to the Task Force have been listed in Table A1.2.

3.2 Block descriptions

. In this section a general description of the vegetation within the blocks is given, along with any recordings of unusual or significant vegetation types. This data has been incorporated into the relevant tables and maps.

3.3 Vegetation map

. The vegetation on Crown land is mapped at a scale of 1:100 000.

. The mapping units used are structural categories; although predominant and associated species of the tallest stratum and species common in the understorey are listed, their distribution is not indicated on the map.

4. Floristic Check-list of the Otway Region - Beauglehole, Carr and Parsons

. This is a check-list of plants identified in the Otway area as a result of survey work concentrated primarily on Crown land.

. Abundance of the species is recorded as:

very common	-	seen in thousands
common	-	seen in hundreds
rare	-	seen in dozens
very rare	-	less than two dozen

. Species are recorded according to the LCC block and the vegetation communities in which they occur.

Communities listed are:

Nothofagus closed forest and Eucalyptus open forest greater than 40 m high

Open forests less than 40 m high on Cretaceous

Open forests less than 40 m high on Tertiary sediments or Quaternary sands

Shrubby woodland or heath

Coastal complex

Salt marsh

Swamps, ponds, water-courses, rivers and soaks

Leptospernum juniperinum - Melaleuca squarrosa closed scrub

Disturbed areas, eg. roadsides and clearings.

5. The Distribution and Conservation of Vascular Plants in the Corangamite-Otway Area (Beauglehole)

. A check-list is given of species on Crown land in the area covered by the LCC Corangamite Report, along with a recording of the sector(s) in which the species occurs and whether or not it was found growing in a reserve. The 'sectors' are areas designated by Beauglehole and do not correspond with the blocks of the LCC report.

. Biological and other reserves, their status and the organisation responsible for their management are listed. Whether or not the reserve has been surveyed and the adequacy of the survey is indicated.

. Four hundred and seventy-five rare, interesting or restricted species are listed. (Rare is used with respect to the Corangamite study area, although an indication is also made where the species is restricted for Victoria.) The sub-blocks in which these species have been identified, and the land status of these blocks (ie. whether a reserve or not), are given.

. An assessment of the reserve status of each of the sectors and of the desirability of additional reserves being created within the sector is included.

6. Inventory of Natural Resources in the Otway National Park - National Parks Service

6.1 Reference Areas

- A detailed description of the structural forms and the vegetation communities has been made for each of the three Reference Areas in the Otway National Park.

6.2 Other areas of the National Park

- A preliminary survey of the vegetation in the remaining areas has been made.

- Vegetation communities for gullies; slopes, ridges and plateaux; swamps and coasts, are described. The different communities are correlated with climate, exposure and bedrock.

- Any interesting features of the vegetation, including particularly good examples of vegetation types, are noted. (See Table A1.2).

TABLE A1.1

CLASSIFICATION OF TREED VEGETATION BASED ON
STRUCTURAL FORMS AND PREDOMINANT SPECIES IN THE TALLEST STRATUM

(Compiled from LCC (1976), Pitt (1981), Parsons et al (1977) and information from the National Parks Service)

STRUCTURAL FORM	PREDOMINANT (marked +) AND ASSOCIATED SPECIES	FORM AND COMMON SPECIES OF UNDERSTOREY	GEOLOGY
Closed Forest	Nothofagus cunninghamii+ Acacia melanoxylon	Shrubs and ferns including Hedycarya augustifolia and Dicksonia antarctica	Cretaceous
Open Forest IV (>40 m)	Eucalyptus regnans+ and/or E. obliqua+	Small trees, shrubs and ferns including Hedycarya angustifolia, Olearia argophylla, Phebalium squameum, Pomaderris aspera and Bedfordia arborescens	Cretaceous
	E. regnans+ with one or more of E. cypellocarpa, E. obliqua, E. viminalis	Sclerophyllous shrubs including Bossiaea cinerea, Leptospermum juniperinum and Melaleuca squamea occur on some of the more poorly drained areas on ths Tertiary sediments	Some minor areas of Tertiary near Redwater Creek
	Forests with differing proportions of E. cypellocarpa, E. globulus, E. obliqua, E. viminalis	Small trees and shrubs including Pomaderris aspera, Olearia argophylla, Bedfordia arborescens, Pimelea axiflora and Tetrarrhena juncea	
	Some areas capable of supporting Open Forest IV have been cleared and now support a secondary scrub of A. melanoxylon and other species typical of the understories of Open Forest IV.		
Open Forests II (15m-28m) & III (28m-40m)	According to Parsons et al (1977), "these forests are variable in structure and the floristics are poorly known".		
	Mixed or pure stands of the following species. Predominant species in mixed stands variable. E. baxteri, E. cypellocarpa, E. globulus, E. ovata, E. obliqua, E. radiata and E. viminalis	Structure and floristics of understorey variable depending on micro-climate and fire history; floristics generally poorly known but include A. mucronata, A. melanoxylon, Goodenia ovata, Pimelea axiflora and Tetrarrhena juncsa	Mostly Cretaceous, some Tertiary
		More sclerophyllous understories contain Banksia marginata, Acacia verticillata, Leptospermum juniperinum, Hakea ulicina, Epacris impressa and Correa reflexa	
		Predominantly grassy understories include Poa sieberana and Poa labillardieri; Themeda australis has been found growing undsr E. globulus.	
		Lsptospermum juniperinum and/or Melaleuca squarrosa have been found on poorly drained Tertiary sites with E. ovata	
	E. aromaphloia+ ± E. obliqua, E. baxteri and E. ovata	Usually sclerophyllous shrubs including A. verticillata, A. mucronata, A. myrtifolia and Leptospermum juniperinum	

(Contd.)

TABLE A1.1 (Contd.)

Open Forest I (< 15 m)	E. globulus+ ± E. sideroxylon	Variable depending on fire history; includes Acacia verniciflua, Pultenaea daphnoides and Goodenia ovata	Cretaceous
	Mixed stands with variable proportions of E. aromaphloia, E. obliqua and E. radiata	Variable but with sclerophyllous shrubs and bracken on Tertiary sediments and with Poa and Acacia on the Cretaceous	Cretaceous and Tertiary
	E. sideroxylon+ with or without E. obliqua and E. cypellocarpa	Mostly shrubby understories with Acacia verniciflua and Pultenaea daphnoides and scattered herbaceous areas with Poa sieberana predominant	Tertiary
	E. obliqua+ E. baxteri	Often shrubby understories with Banksia marginata, Epacris impressa, Hakea ulicina and Xanthorrhoea australis	Tertiary
	E. viminalis	Pteridium esculentum, Poa spp. and Lomandra longifolia	Quaternary sands
Woodland	Some pure stands and mixed species woodlands with E. baxteri, E. nitida, E. obliqua and E. radiata. Predominant species variable	Heathy understorey with Banksia marginata, Leptospermum juniperinum, L. myrsinoides, Persoonia juniperina, Dillwynia spp. and Xanthorrhoea australis	Tertiary
	E. kitsoniana+ ± E. baxteri, E. obliqua and E. ovata	Scrub understorey with Leptospermum juniperinum, Epacris impressa, Leucopogon parviflorus and Bossiaea cinerea	Tertiary

TABLE A1.2

SIGNIFICANT SPECIES OR COMMUNITIES THAT HAVE BEEN IDENTIFIED IN THE OTWAYS AREA AND CONSERVATION STATUS WHERE KNOWN

(Compiled from LCC (1976), Pitt (1981), Information from the National Parks Service, Beauglehole (1980), Parsons et al (1977) and Duncan and Isaac (Pers. comm.))

COMMUNITIES	
E. kitsoniana woodland (bog gum)	The only occurrences of this species in Australia are at Wilson's Promontory and surrounding areas, Portland-Lower Glenelg and the Otways, where it occurs on acidic soils near Cape Otway. It has been listed in "Australian Endangered Species" by Pryor. It is included within the Cape Otway National Park and the Stony Creek Reference Area, but the extent of the community within the park compared with that in other areas is unknown.
E. regnans open forest (mountain ash)	In the vicinity of Redwater Creek, E. regnans grows on Tertiary quartz sands; this is possibly a unique situation. The trees presumably obtain sufficient nutrient from the Cretaceous sandstones and mudstones below the sands. Some E. regnans on Tertiary sediments is included in a Flora and Fauna Reserve to be managed by the Forests Commission.
Nothofagus closed forest (myrtle beech)	Some of the best examples in the State of this uncommon community occur along rivers in the northern part of Cape Otway National Park. The Calder River Reference Area contains some closed forest with Nothofagus. The quality of this community outside the National Park is unknown, though it occurs within the Melba Gully Flora and Fauna Reserve, Barramunga Educational Area and the Aire Forest. Its precise distribution has not been mapped.
SPECIES	
Amphibromus recurvatus (dark swamp wallaby grass)	It occurs on uncommitted Crown land on the northern slopes of the Otway Ranges south-east of Barongarook; it is not known from reserves in the Otways.
Boronia muellerii (forest boronia)	Reaches the western-most extremity of its range in the Otways. It occurs in the Otway National Park as well as surrounding hardwood production areas.
Burnettia cuneata (burnettia lizard orchid)	A rarely observed species that has been found on uncommitted Crown land near Devondale. It is not known from any reserve.
Correa backhousiana	A rare species found along the coast between the Parker River and Cape Otway in the Caps Otway National Park.
Correa reflexa var nummularifolia (common correa variety)	A variety of common correa known in Victoria only from north of the Parker River. Due to its locality, it is probably within the Cape Otway National Park.
Cyathea cunninghamii (slender tree-fern)	Slender tree-fern reaches the westernmost limit of its range in the gullies of the Otway Ranges. It occurs within the Cape Otway National Park and the Angahook-Lorne State Park, in the Aire River Flora and Fauna Reserve and the Aire Forest.
Cyathea marcescens (skirted tree-fern)	It is not known outside Victoria where it is localised in four isolated mountain areas - the Otways, Strzeleckis, and East Gippsland. In the Otways it occurs along the Parker River and is presumably within the Cape Otway National Park.
E. brookerana ? (Tasmanian swamp gum)	Populations of swamp gum have been identified which may be E. brookerana rather than E. ovata. This still needs to be resolved. Populations of each species occur in the Otway National Park.
E. globulus (blue gum)	There is continuous variation in the populations of E. globulus; four main core populations have, however, been recognised by Kirkpatrick (1975) and are given sub-species status. The populations of E. globulus in the Otways within approximately 0.5 km of the coast are closest to sub-species globulus, the core population of which occurs in Tasmania, while the populations further inland tend toward pseudoglobulus. Most populations of E. globulus occur in the Cape Otway National Park and the Lorne-Angahook State Park. A map of the distribution is given in Parsons et al (1977).

(Contd.)

E. regnans x E. obliqua (Otways messmate)	Otways messmate is a hybrid between E. regnans and E. obliqua. A relatively large population of Otways messmate occurs within the Cape Otway National Park but its status with respect to the once only logging in the National Park is unclear.
E. sideroxylon (red ironbark)	In the Otways, E. sideroxylon occurs as an interesting coastal outlier in a small locality of approximately 13 miles diamster. At least part of this stand occurs in the Angahook-Lorne State Park.
Helichrysum rogersianum	The Otways is one of the three areas where this plant, endemic to Victoria, occurs. It has been located within the Crinoline Creek Reference Area and in the Western Otways Forest.
Leptorhynchus gatesii (wrinkled buttons)	This is a rare Victorian endemic species, known only from the Lorne area where it is not included in any reserve.
Lycopodium varium (long clubmoss)	This species is extremely localised, known only from three localities in Victoria. In the Otways it occurs in the Cape Otway National Park at Mait's Rest and along the upper Calder River.
Phebalium squameum (satinwood)	This species is widespread in Tasmania but known on the mainland only in the Otways, where it is locally common, and from the Macalister River and Mt. Elizabeth in eastern Victoria. It is found in several reserves in ths Otways.
Prasophyllum beaugleholei (midge orchid)	It is extremely localised and rare and known from only three localities in Victoria. In the Otways it occurs on uncommitted Crown land near Barongarook and it has also been recorded in the Cape Otway National Park.
Prasophyllum flavum (yellow leek-orchid)	This is a rare species which has been recorded from the Stony Creek Reference Area.
Sarochilus australis (Gunn's orchid)	This is an uncommon ephiphytic orchid. Its most westerly occurrence is in ths fern gullies in the Cape Otway National Park.
Tetrarrhena acuminata (pointed rice grass)	Localissd and rare in Victoria, it occurs in swampy areas in the Carlisle heathland in both a Flora and Fauna Reserve and from the Carlisle State Park.
Thelymitra vsnosa (veined sun-orchid)	The veined sun-orchid is locally frequent in the alpine and sub-alpine arsas and has isolated occurrences at lower altitude in East Gippsland and the Otways. In the Otways it is known from uncommitted Crown land at Dsvondale and from the Carlisle State Park.
Tmesipteris elongata	A rare species recorded from two areas in Victoria. It is found in the Cape Otway National Park.
Asplenium flaccidum (weeping spleenwort)	Scattered in ths wetter and cooler mountain forests of southern Victoria. It has been recorded from the Herbarium Grids of K35, K42 and K43; the exact localities are unknown but these grids cover the area south of Beech Forest, the Mount Sabine area and the forests to the north east.
Hypolepis australis (Austral ground-fern)	Uncommon and scattered along streams in a few forests of southern Victoria. Recorded from Herbarium Grid K42 (see Asplenium flaccidum for area covered) in the Otways.
Lastreopsis hispida (bristly shield-fern)	Uncommon and confined in Victoria to very shaded gullies. This fern has been recorded in the Otways in Herbarium Grids K42 and K43 (see Asplenium flaccidum for area covered by these grids).
Mecodium rarum (narrow filmy-fern)	This filmy fern, which occurs in shaded mountain gullies, is uncommon in Victoria.

CURRENT MANAGEMENT OBJECTIVES, STRATEGIES AND PRESCRIPTIONS FOR CROWN LAND

1. National Parks

There is only one National Park within the Otway Area - the Otway National Park - which is managed by the National Parks Service. It covers approximately 12,750 ha.

1.1 Plan of management for Otway National Park

A draft of the first management plan for the Otway National Park has been drawn up based on an investigation into the natural resources of the area. Some of the proposed strategies and prescriptions more relevant to this report are given below. All quotations are from this draft Plan.

1.1.1 Basic management concepts

The park will be managed to preserve, protect and interpret its important natural, scenic and historical values. Recreation, education and scientific investigation will be encouraged subject to controls necessary to prevent undesirable impacts.

> "Land uses conflicting with the protection and preservation of natural values will be phased out and management will generally seek to gradually bring fauna and vegetation back to a state more closely resembling the environment which existed immediately prior to European settlement. Special attention will be given to Reference Areas and other reserves."

1.1.2 Zoning

The park has been divided into the following zones each with particular management objectives:

(i) Protection Zone - to protect stone forest and fossil beds.

(ii) Reference Zone - there are three Reference Areas within the park.

(iii) Conservation and Recreation - this zone will eventually cover the majority of the park as commercial land uses are phased out.

(iv) Special Recreation Zones.

(v) Special Management Zone - this is to protect the very diverse habitats at the mouth of the Parker River.

(vi) Limited Utilization Zone - within this zone there will be some utilization of resources until these uses are phased out.

1.1.3 Management objectives and prescriptions

These are given for three aspects of park management:

(1) Grazing and logging

These commercial land uses are not usually permitted within a national park, but the final recommendations of the LCC allowed grazing and logging to continue for a limited period within areas of the Otway National Park.

Draft management objectives are:

. "to minimise the impact of logging and grazing on park values as far as is practicable"

. "to ensure that all such activities are conducted under appropriate permits which contain conditions controlling their operation"

Management requirements (based on the published Final Recommendations of the LCC) include:

. existing grazing licences to be terminated as soon as practicable but not later than 1985

. low intensity timber production to be phased out no later than 1988. These operations to be conducted by the Forestry Commission in consultation with the National Parks Service.

(2) Reference Areas

The management aim, as stated in the draft management plan, is: "to ensure that these areas are maintained in perpetuity in a relatively undisturbed state and that natural processes are allowed to continue". Separate resource inventories and management prescriptions have been drawn up for the Reference Areas.

(3) Management of indigenous flora and fauna

. "to maintain and, where necessary, re-establish native flora and fauna similar to that which occupied the area immediately prior to European settlement"

. "to minimise the effect of logging, grazing and recreation activities on the native flora and fauna".

Actual practices include:

. protection of the Nothofagus cunninghamii - Acacia melanoxylon alliance from the effects of logging, grazing and recreation

- protection of the E. baxteri - E. kitsoniana alliance
- protection of the Melaleuca squarrosa - Leptospermum juniperinum alliance with re-alignment of the Great Ocean Road
- management to maintain the diversity of plant associations and habitats at the mouth of the Parker River.

(4) Vermin and noxious weeds

These are to be eradicated or controlled to keep populations and infestations as low as possible.

(5) Fire management and control

The objectives are:

- "to take all reasonable measures to prevent the outbreak and spread of wildfires"
- "to take adequate precautions for the safety of visitors and surrounding landowners"
- "to develop a fire management strategy which protects the park from injury by fire and which may use fire for the management of natural ecosystems".

Prescriptions include:

- control of wildfires as rapidly as possible
- the development of fire protection plan
- investigation of the role of fire in the maintenance of the communities of the three Reference Areas.

2. State Parks

The Angahook-Lorne State Park and the Carlisle State Park are the two State Parks within the Otway area and they are managed by the FCV. Their combined total area is 24,000 ha.

No detailed inventory of the natural resources, including vegetation, has been compiled; vegetation information that is available is that covered by the LCC Corangamite report, the land system tables of the SCA report, and that provided by local conservation/field naturalist groups. The only formal definition of objectives is that provided by the LCC in the Final Recommendations for the Corangamite Area. No specific management plans outlining management strategies or containing management prescriptions have yet been drawn up. The following management proposals, however, have been obtained from the District Forest Officers responsible for looking after the two parks.

2.1 Carlisle State Park

- There will be no logging.
- FCV will continue to carry out fuel reduction burns for the purpose of protection from wildfire. The areas with scattered eucalypt cover have been burnt in the spring approximately every five years for the past thirty years.
- No facilities will be provided for the public for a long time.

2.2 Angahook-Lorne State Park

- There will be no logging.
- Fuel reduction burns to protect private property will cover approximately one third of the forest. Near the townships of Lorne, Wye River, Moggs Creek, Fairhaven and Aireys Inlet, burning will be on a three to five year cycle.
- Liaison with local Shires and conservation groups will be established.

3. Hardwood Forests

The primary purpose of hardwood forests is the production of timber; the value of these forests for other purposes such as recreation, landscape, water catchment, flora conservation and animal habitat, however, is well recognised. The LCC in the Final Recommendations for Corangamite, recommended that maintenance of these values be a second objective for the management of the hardwood forests.

The question of level of management for these secondary objectives, however, has not been specified, except in a couple of instances. This becomes an issue because the different uses seek to optimise different aspects of the processes occurring within the forest. For example, hardwood production, which aims to maximise the amount of timber harvested, will log the forest before the rate of increase in biomass declines and regenerate the area with seedlings which have a much greater rate of biomass accumulation; the forest is therefore logged before it has reached full maturity. The management of a forest for water production purposes, on the other hand, aims to maximise the volume and quality of water leaving the catchments and volume and quality reaches a maximum in the mature stand.

If a forest is to be managed for more than one purpose, a compromise must be reached in which the area no longer functions at maximum capacity for one use but at a reduced capacity for two or more uses. Conflict inevitably arises over the relative importance of each value and the degree to which optimum management for one use should be compromised for another.

The particular compromises which are reached will always be a contentious issue; as little guidance has been given by the LCC as to the degree of compromise for any given use, the decisions are presumably up to the Forests Commission to make. Although the Forests Commission has logging plans for the areas to be logged in the next three years and also logging prescriptions, there does not appear to be any overall statement of the objectives of management of the Otway forests, including the objectives of management for non-timber uses, and an outline of the stragegies to be implemented to achieve these objectives.

The current management strategies for the Otways, for which the objectives are not entirely clear, are summarised below:

. The hardwood forests contain two broad forest categories, the Mountain Forests and the Foothill Forests. The Mountain Forests generally correspond to the Open Forest IV mapped in the Otway area by the LCC, while the Foothill Forests correspond to Open Forests I, II and III and to the Woodland. Management varies slightly between the two forest types.

. Harvesting in the Mountain Forests usually involves clear-felling due to the high proportion of suitable trees for sawlogs. Harvesting of the Foothill Forests is usually by selective logging which creates small gaps.

. Species harvested include: E. regnans - mountain ash; E. globulus - blue gum; E. cypellocarpa - mountain grey gum; E. obliqua - messmate; E. baxteri - brown stringy bark; E. viminalis - manna gum; and E. radiata - narrow leaf peppermint.

. Plans showing areas to be logged are available for three logging seasons in advance and are drawn up after consultation with the millers who may have preferences for certain species, depending on the market.

. The minimum age for harvesting the ash forests is approximately 60 years. This is a minimum value, not necessarily the optimum age, which would, presumably, be used in preference.

. No clearing of the gully vegetation in the Mountain Forests as mapped on the 1:25 000 resource map is proposed.

. Non-eucalypt vegetation on good quality sites in the Mountain Forests may be cleared and replanted with species suitable for harvesting for timber.

. No fuel reduction burns will be carried out in the Mountain Forests due to the sensitivity of some species, in particular E. regnans, to firing, and hence the ease with which the timber resource could be destroyed in the event of the burn flaring into a wildfire.

. Fuel reduction burns are the responsibility of District Foresters. In particular, northern faces and strategic areas, for example around areas of development, are subjected to fuel reduction burning. Burning tends to be concentrated along roads in readily accessible areas and is usually carried out once every five to ten years, the precise interval depending on seasonal conditions.

. Control of harvesting operations:

(i) harvesting is to be carried out with reference to Standing Instruction M-102 (attached at end of Appendix 2).

(ii) within water supply catchments, operations also need to conform with the management prescriptions drawn up in conjunction with SCA. These prescriptions have been approved for the Upper Barwon and Painkalac Creek Water Supply Catchments and have yet to be approved for the West Barham and Gellibrand River Catchments.

(iii) there is a third set of interim prescriptions which apply to the harvesting of sawlogs and pulpwood from the Otways district (attached at end of Appendix 2).

THE EFFECTS OF PARTICULAR MANAGMENT STRATEGIES AND PRACTICES ON THE VEGETATION

1. Fuel Reduction Burning

The aim of fuel reduction burning is to burn leaf, bark and twig litter and the shrubby understorey, thereby reducing the volume of flammable materials and with it the hazard of a wildfire. Such burns usually kill the understorey vegetation; most tree species usually survive unless the fire intensity is locally high for some reason.

Fuel reduction burns affect the species composition of the vegetation directly by influencing the survival of populations. Different species have different tolerances to firing and it is necessary to know these, along with the particular fire regime, before the effects, including long-term effects, can be assessed.

As well as affecting the vegetation directly, fuel reduction burns will also affect other components and processes within the environment such as soil structure, soil microfauna and flora, nutrient mobilisation, nutrient loss, etc.; changes to these components may affect the vegetation, though possibly only after a long period of time.

1.1 Fire regime

The fire regime consists of three components: the intensity of burn, the season of burn and the frequency of burn. The intensity will affect such aspects as seed germination and whether a plant is killed by a given fire; season of burn affects the ability of seeds which germinate to survive and the stage of development of the plant at the time of burn, for example, whether the plant is flowering or fruiting; the frequency of burn is important in determining the survival of plant populations requiring fire at particular stages in their life cycle, or the absence of fire at particular stages.

Fuel reduction burns impose a particular fire regime; the intensity of burn is usually low compared with wildfires, the season of burn is usually in spring when conditions are moist and the danger of the burn

flaring into a wildfire is reduced and the frequency of burn is variable depending on the local vegetation type, the litter/shrub condition and the proximity of forests or private property requiring protection.

The relative effect of fuel reduction burning, ie. the changes brought about by the implementation of a new regime, will depend on the previous fire regimes. There is usually much debate as to what these were prior to European settlement, due to a lack of knowledge of the fire regime produced by either Aboriginal burning or by lightning. Perhaps the important question, however, is how continuation of fuel reduction burns will affect the future development of the vegetation.

1.2 Plant adaptations and responses

There are many plant attributes which affect the way the vegetation responds to firing. These include -

- the ability of the adult plant to survive firing, for example, through the development of epicormic buds and lignotubers
- the ability of seeds to germinate after firing
- the necessity of firing to initiate flower development
- the length of time for plants to reach reproductive maturity; this affects the time interval between firing if particular species are to survive.

There are many species for which some or all of these attributes are not known. Given below is a summary of the attributes which are known of a few of the more common species:

- E. regnans (mountain ash) - The mature plant is sensitive to firing and is unable to regenerate from epicormic buds or lignotubers. Seeds held within the fruits will germinate after fire but there is little storage of viable seed within the soil so that regeneration does not occur from soil seed stores. It takes approximately 10-20 years for the tree to mature to first seed production, so that a frequency of fires greater than once every 10-20 years with an

intensity high enough to kill the mature plant, will eliminate E. regnans from a site. There is evidence to suggest that E. regnans regenerates better after a fire or may, in fact, require firing for regeneration. In this case, a fire within the life span of the individual, approximately 250 years, is needed to maintain the population.

. Nothofagus cunninghamii (myrtle beech) - Mature plants are able to shoot from a basal burl after firing, though frequent firing or a very intense fire is likely to result in the degradation of the Nothofagus forest.

. Acacia dealbata, A. mearnsii, A. melanoxylon (silver wattle, black wattle and blackwood) - Although these species will be killed by firing, there is usually seed storage within the soil which will allow regeneration. If, however, the firing frequency is particularly high, the interval between fires being less than the time taken for the individual plants to reach reproductive maturity, these species will eventually be lost from a site. On the other hand, if the length of time between fires is greater than either the longevity of the plant or the length of time for which seed will remain viable in the soil, then this will also result in the loss of these species unless they are able to colonise from an adjacent area.

. General comments on other species.

Many heath species have adaptations to withstand firing and it seems that some, for example Casuarina pusilla, Leptospermum myrsinoides and Lepidosperma laterale, may require firing at frequencies greater than once in fifty years in order to maintain the populations. More information is needed, however, on the effect of season of burn on the survival of individuals and germination of seeds.

1.3 Changes to other components of the environment.

The effect of fuel reduction burning on soil structure, soil micro-organisms, nutrient mobilisation, etc. will also influence the vegetation; however, except for nutrient cycling, there has not been enough time in this assessment to review the work that has been done on the effect of fuel reduction burning on these other components of the environment. Since regeneration burning and harvesting also both affect nutrient cycling, the effects of all three are discussed together in section 3.4.

2. Regeneration Burning

It has been found that burning of a site prior to seeding helps in the germination and establishment of seedlings. Burning removes the cover of branches, bark and twigs (slash) remaining after harvesting and also increases the availability of nutrients.

Regeneration burning may not only have beneficial effects. It will also cause loss of nutrients stored in the logging debris in smoke and through leaching and erosion. It will also affect soil microflora and soil structure. The effect on nutrient cycling will be discussed in Section 4.

Regeneration burning may also kill any understorey plants not already damaged or killed by timber harvesting and there is the possibility that any areas left as reserves or buffer strips will also be damaged.

3. Timber Harvesting

Clearfelling of large coups results in even-aged stands when the cleared areas are regenerated; clearfelling of the foothill forests where stands are usually of mixed age may, therefore, reduce the structural diversity within the stand. Although not common practice, these clearfelled areas could also be regenerated with the one species, which would reduce the diversity of the tree layer.

Selective logging, which has been the practice in foothill forests, allows the maintenance of mixed-aged stands, although the tree stratum of the mature stand usually becomes more uniform with respect to species composition since logging is usually of only one or two of the component species; whether the stand regains its original diversity in the following generation depends on the regeneration methods used.

Reduction in the structural diversity of a forest also results from logging usually being carried out when the trees reach a particular stage of maturity; this leaves no areas of very mature forest, unless reserves are left.

Timber harvesting requires the development of roads and tracks; these open up the forest and are mostly the areas in which weeds and exotic species become established. Harvesting may also facilitate the introduction of pathogenic organisms.

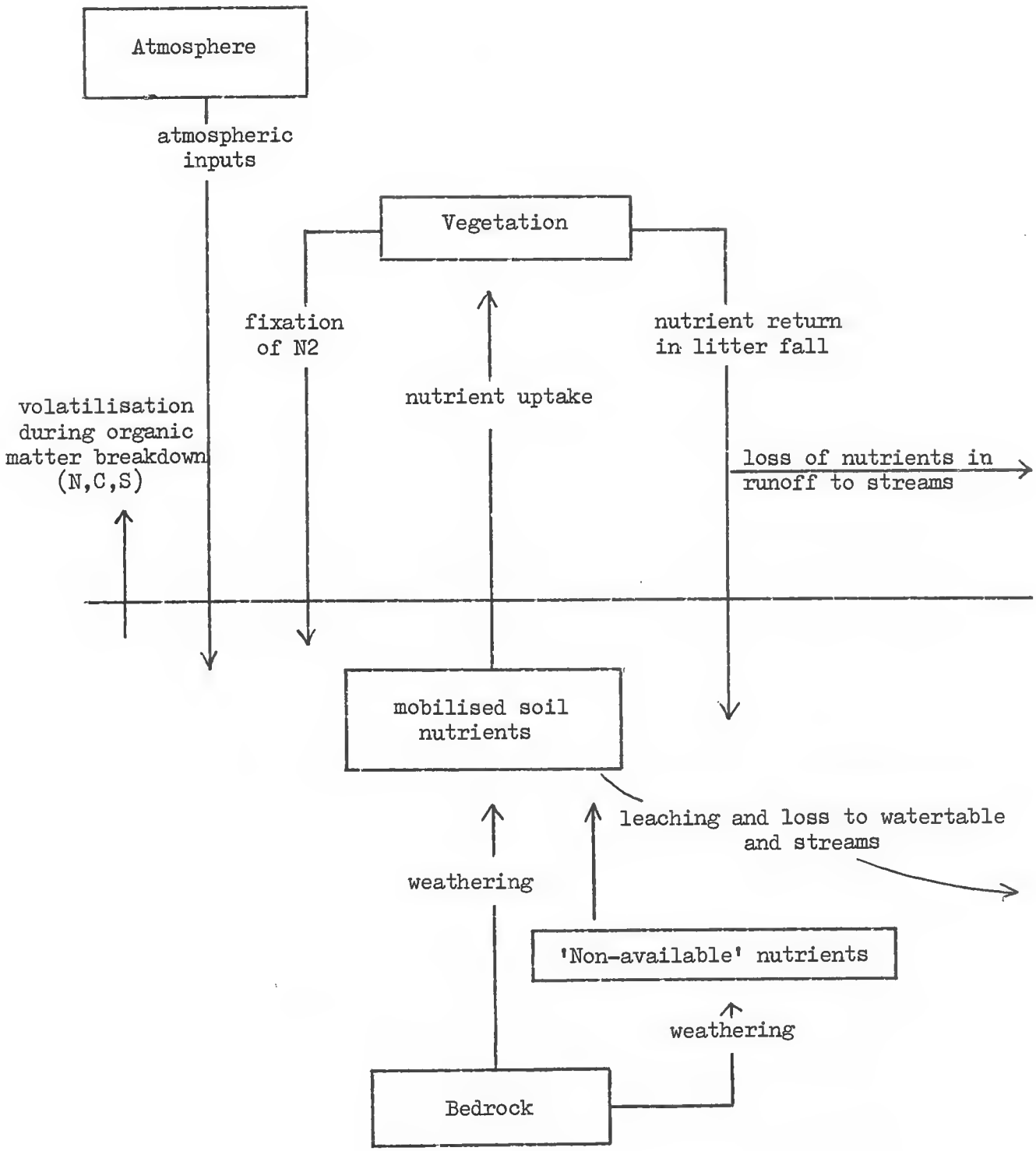
Removal of vegetation and trafficking of the cutting area by vehicles will result in soil compaction and erosion and hence gradual site deterioration. This may have implications for the vegetation in the long term after repeated logging; the deterioration may be more in the general quality of the vegetation rather than species composition. At logging landings, however, extreme soil compaction is probably one of the main factors responsible for the general paucity of regenerating plants and indicates that when compaction is severe, plant growth may be inhibited.

The significance of the removal of nutrients in harvested timber will be discussed in the next section.

4. Nutrient Cycling and the Effect of Harvesting and Fuel Reduction and Regeneration Burning

The atmosphere, bedrock, soil and vegetation are the four major components of the environment containing nutrients. The movement of nutrients within and out of a system consisting of these components, which is not being harvested or fired, is shown diagramatically in Figure A3.1.

FIGURE A3.1


Atmosphere
atmospheric inputs
Vegetation
fixation of N2
nutrient uptake
nutrient return in litter fall
volatilisation during organic matter breakdown (N,C,S)
loss of nutrients in runoff to streams
mobilised soil nutrients
leaching and loss to watertable and streams
weathering
'Non-available' nutrients
weathering
Bedrock

The sources of input of nutrients into the soil and plant components of the system are:

. atmospheric inputs - dry fall out and precipitation

. atmospheric fixation (mainly nitrogen)

. weathering of the bedrock.

Nutrients can be lost from the soil and plant components -

. in soil particles in runoff, particularly after logging or burning

. through leaching

. in removal of timber

. in particulate loss in smoke during burning

. volatilisation

It seems that the basic information needed in an assessment of the significance of the loss of nutrients from the plant and soil components, due to removal of timber and through fuel reduction and regeneration burns are:

. the masses of available nutrients and the nutrient balances required to maintain the productivity of the different forests

. the total reserves of available nutrients within the mass of soil available to plant roots

. the mass of nutrients lost during the rotation interval and the nutrient input during the same length of time. If nutrient outputs exceed inputs over the same time period, there will be a depletion of the soil nutrient reserves, presumably eventually to a level below which the quantity and/or quality of regrowth vegetation declines. The length of time taken to reach this point depends on the difference between output and input, the size of the nutrient reserves available in the soil and the length of the rotation.

. the reserves of non-available nutrients within the mass of soil available to plant roots; this includes the mass of nutrients within the bedrock. The length of time over which repeated forest rotations can be sustained depends on this total reserve of non-available nutrients from which nutrients are gradually made available. Soils with very low total nutrient reserves would not have the capacity to sustain several forest rotations.

The nutrient pools associated with the standing biomass and forest litter, the soil reserves of available and non-available nutrients, and the rate of input and output of nutrients to and from the available nutrient/plant component, are discussed in the following sections. Of these factors, the only ones for which any information is available in the Otways are the soil reserves of some of the available and non-available nutrients, although this data is inadequate for several reasons.

4.1 Nutrient content of standing biomass

There have been several studies that have examined the nutrient content of the different tree components - heartwood, sapwood, bark, twigs and leaves - of different Eucalypt species. Studies which have involved species found in the Otway area include Attiwill's study of E. obliqua from Mt. Disappointment in the Great Dividing Range; Feller's study of an E. obliqua - E. dives forest and an E. regnans forest in the Maroondah Catchment; and Ashton's study of phosphorus in components of an E. regnans forest near Beenak. The total masses of nutrients in the above ground components of the different species and the proportion of the biomass and of each nutrient in the different components are given in Tables A3.1 and A3.2. Except for Attiwill's study, the masses of nutrients in the understorey are also given. (See Table A3.3).

Although these species, excluding E. dives, are found in the Otways, none of the studies were of trees from the area and there may be local differences in nutrient masses due to differences in the concentrations of nutrients and/or in the biomass per hectare. Attiwill found

significant differences in P, K, Mg and Ca concentrations in stemwood (sapwood plus heartwood) attributable to site variation, so it seems that differences in concentration are a likely source of error if extrapolation to the Otway area is made.

Attiwill's study is the only one which examines the amount of nutrients in the biomass at different ages of the plant. As would be expected, the mass of nutrients increases with increase in mean age of the forest from 44 years to 66 years. The forest ages in Ashton's and Feller's study are 27 to 38 years respectively, and it should be noted that this age is below that at which harvesting is likely to occur. It is therefore probable that nutrient loss through harvesting and subsequent burning would be greater than these studies indicate.

4.2 Nutrient content of litter

Studies on the biomass and nutrient content of litter in E. regnans, E. obliqua, and E. obliqua - E. dives forests have been made. Data from these studies are summarised in Table A3.4.

4.3 Soil nutrient reserves

An estimate of the quantities of nutrients in the top 120 cm of several soils in the Otways region has been made and is given in Table A3.6. These values have been calculated from the concentrations of nutrients measured for various soils under native forest by Pitt (1981); these soils have been selected on the basis of available nutrient data and are not necessarily typical of the soils of the hardwood production forests. The quantities derived may only be regarded as an estimate due to:

(i) no bulk densities being measured for these soils. The bulk densities used to calculate nutrient quantities were obtained from measurements of bulk densities of soils under similar vegetation in other localities, hence they may only be regarded as approximate (see Table A3.6).

(ii) lack of nutrient concentration measurements for several horizons. As it was necessary to have values for all soil horizons down to 120 cm in order to have some estimate of nutrient mass to this level, values for those horizons where no measurements were made were estimated from other measurements within the profile or from profiles on similar soils.

(iii) heterogeneity of the soils in space and lack of a sampling intensity to take account of this variability; ie the nutrient concentrations given may not be representative

(iv) the possibility of variation in soil nutrient reserves with age of the forest

(v) no account being taken of the rockiness of the soil profile; the values calculated are based on a profile from which rocks are absent and will therefore over-estimate the nutrient mass of a profile with rocks.

4.4 Natural inputs and outputs of nutrients

Nutrient inputs in precipitation and output in stream water have been measured by Guthrie et al (1978) in an E. obliqua forest and by Feller (1981) in an E. regnans forest. Both forests were in the Dividing Range.

The study by Feller, however, is the only study to try and estimate nutrient input through geological weathering. The values obtained are calculated on the basis that nutrient output in overland flow and leaching, plus the mass of nutrient taken up by the plant, must equal the nutrient input from precipitation and geological weathering, provided the nutrient doesn't become bound in the soil.

The calculated nutrient inputs from bedrock weathering are given in Table A3.7. These values have been given so that some estimate of the effect of harvesting and burning on nutrient balances can be made for at least one ecosystem. It should be realised, though, that these values cannot be extrapolated to the Otways, where the soil parent material is Cretaceous sandstone or unconsolidated Tertiary sands and clays.

4.5 Nutrient outputs from harvesting and burning compared with nutrient inputs

Nutrient loss from harvesting and burning during a rotation depends on:

- the age of timber harvested
- the tree components removed by harvesting
- the intensity of burning which will influence the quantity of material burnt and also soil factors that in turn influence the amount of leaching
- the type and age of understorey burnt
- the frequency of burning during the rotation
- the rapidity of vegetation establishment after burning which will affect the extent of nutrient loss in erosion and leaching
- climatic factors during and immediately after burning which will affect erosion and leaching losses

The number of factors influencing nutrient loss make a comparison of nutrient loss compared with input difficult, a situation compounded by the fact that little data is available on the quantities of nutrients lost from burning in smoke and through leaching and erosion after burning. A simplified comparison of inputs and outputs can be made for the 38 year E. regnans forest described by Feller (1980) by using the nutrient input data given in Tables A3.7 and A3.11, assuming either -

(i) no fuel reduction burning and complete loss at harvesting of all nutrients in the above ground biomass (including understorey) and litter (see Table A3.8). This would overestimate likely nutrient loss from a logging situation, or

(ii) no fuel reduction burning and the only nutrient loss being that due to removal of stemwood (see Table A3.9). This would underestimate likely nutrient loss.

(Note: Tables A3.8 and A3.9 only consider nutrient input required to replace that lost in the biomass; input required to replace leaching of soil reserves has not been included. The values in Table A3.10 can be used as a rough approximation to the amounts lost through leaching though they represent the loss at only one stage in the development of the forest.)

A comparison of the data on nutrient losses (Tables A3.8 and A3.9) with that on inputs from weathering (Table A3.7) and precipitation (Table A3.11) suggests that in the Maroondah forests it is likely that P, Na, Mg and Ca will probably be adequately replaced but that the replacement of K appears to be insufficient to maintain the reserve of this nutrient which will, therefore, gradually be depleted. The length of time over which this depletion will occur depends on the nutrient reserves in the soil and the rate of loss.

There are numerous factors, however, some of which are discussed in the next section, which may mean that the above assessment is incorrect. One factor that has not been considered but which is particularly important is the depth of weathering bedrock. It may be that the nutrients being released are at a depth below that available to the tree roots. If this were the case, the forest would be dependent on existing soil reserves, nutrient input from precipitation and from nutrient cycling, which would mean that nutrient removal through harvesting and burning could be much more significant.

Also, this assessment is only of the nutrient input to and output from the total system. Many of the nutrients released from bedrock weathering will be incorporated into secondary minerals and hence will be unavailable to the plants. Forest regeneration is dependent on adequate soil reserves of available nutrients. Whether reserves remain adequate for successive forest rotations depends on the size of the reserves of available nutrients, the rate at which non-available nutrients become available and the rate of nutrient removal in harvesting, burning and leaching.

The analysis carried out is obviously fraught with problems, largely arising from inadequacies in knowledge of processes and interrelationships and a lack of appropriate data.

4.6 Problems associated with the assessment of the significance of nutrient loss

4.6.1 Definition of significant loss

As Turner (1981) points out, "assessments of the impacts of nutrient removals are often carried out within ill-defined guidelines such as 'minimal loss' or 'insignificant decreases in production'". Determinations of what are considered to be 'minimal losses' or 'insignificant decreases in production' need to be made. As yet, no such determinations have been made for any ecosystem.

Decrease in productivity can occur well before nutrient decline is such that the soil is no longer able to support growth of the same species.

4.6.2 Nutrient imbalances

It may be that an imbalance of nutrients resulting from nutrient removal may be more limiting in its effect than that of the mass of one particular nutrient removed. (Turner, 1981).

4.6.3 Soil nutrient reserves

The nutrient budget calculated using Feller's data looked at inputs and outputs to the total soil/plant system. While this will give an indication of whether there is an overall input or output of nutrients from the system under harvesting, it avoids the question of the nutrient store within the soil.

The soil component contains nutrients which may be in available or unavailable form; those in unavailable form are usually incorporated in primary minerals or, to a lesser extent, are organically bound.

These primary minerals and organic compounds represent a store of nutrients which will be available for plant growth at some stage in the future. These need to be accounted for in nutrient cycle studies but are rarely adequately measured in routine soil studies; the nutrient data for the Otway soils in the report by Pitt is a case in point.

The following points with respect to soil nutrient reserves are important in considering the impact of nutrient removals:

. the extent of the primary mineral and organic reserves in the accessible soil volume. Young soils will generally have much larger reserves than old soils which are highly weathered. Nutrient removals from soils without primary mineral reserves will obviously be much more significant.

. in determining the extent of soil reserves of both available and unavailable nutrients, consideration needs to be given to
  - the spacial variation, both laterally and vertically, of these reserves
  - the accessibility of the reserves to plant roots. (This will be influenced by the age of the plants; older, mature forests can obtain nutrients from greater depths than young forests. Short rotation forests may, therefore, obtain nutrients from the more surficial layers of the soil.)

. the rate at which nutrients are released from the soil reserves. Although total nutrient reserves may be adequate to supply several crop rotations, the rate at which any one nutrient is made available may be limiting, particularly at the point of crown closure when nutrient demand is greatest. (Turner, 1981)

4.6.4 Length of time over which loss occurs

Turner (1981) points out that "the system assumes that gradual inputs can overcome the effect of a single pulsed loss" and that "this aspect of nutrient dynamics has rarely been considered".

TABLE A3.1 BIOMASS AND MASS OF NUTRIENTS IN THE ABOVE GROUND COMPONENTS OF *E. REGNANS* AND *E. OBLIQUA*

SPECIES AND COMPONENT PARTS	BIOMASS t/ha	NUTRIENT MASS kg/ha					
		N	P	K	Na	Mg	Ca
E. regnans	(from Feller, 1980) Forest age: 38 yrs.						
stemwood	490.6	113	9	898	64	78	157
stembark	67.8	88	11	241	40	68	424
branches	39.9	36	3	118	7	13	83
leaves	2.6	35	3	24	2	6	13
Above ground total:	601.1	282	26	1285		168	694
E. regnans	(from Ashton, 1976) Forest age: 27 yrs.						
stemwood) stembark)	113.1		10.10				
branches	71.2		3.89				
leaves	8.1		1.79				
Above ground total:	792.4		15.78				
E. obliqua	(from Feller, 1980) Forest age: 38 yrs. (Mixed *E. obliqua* - *E. dives* forest)						
stemwood	256.6	216	6	28	36	20	79
stembark	79.5	130	5	39	48	18	119
branches	23.8	31	3	15	10	18	30
leaves	3.8	26	2	16	6	10	22
Above ground total:	363.7	402	17	98	100	67	251
E. obliqua	(from Attiwill, 1980) Mean tree age: 43.7 yrs. (1st column) 66.2 yrs. (2nd column)						
stemwood			9.1 14.5	41.2 62.6		18.8 29.7	23.7 32.0
stembark			5.2 6.9	100.2 134.9		83.6 121.7	160.5 216.6
branches			3.0 6.3	24.0 52.7		24.7 55.0	51.0 103.0
leaves			4.1 6.0	23.7 37.2		20.5 38.3	19.7 28.0
Above ground total:			21.4 33.7	189.1 287.5		147.6 244.7	254.8 379.5

TABLE A3.2 PROPORTION BIOMASS AND NUTRIENTS IN ABOVE GROUND COMPONENTS OF LIVING *E. REGNANS* AND *E. OBLIQUA*

SPECIES AND COMPONENTS	PROPORTION OF BIOMASS AND NUTRIENTS IN THE ABOVE GROUND COMPONENTS OF LIVING TREES (% of total mass)						
	BIOMASS	N	P	K	Na	Mg	Ca
E. regnans	(from Feller, 1980) Forest age: 38 yrs.						
stemwood	82	40	34	70	56	46	23
stembark	11	31	42	19	35	40	61
branches	6	17	12	9	7	10	14
leaves	<1	12	11	2	2	4	4
E. regnans	(from Ashton, 1976) Forest age: 37 yrs.						
stemwood) stembark)	90		64				
branches	9		24.7				
leaves	1		11.3				
E. obliqua	(from Feller, 1980) Forest age: 38 yrs. (Mixed *E. obliqua* - *E. dives* forest)						
stemwood	71	54	37	29	36	31	32
stembark	22	32	32	40	48	27	47
branches	7	8	18	16	10	27	12
leaves	1	7	12	16	6	14	9
E. obliqua	(from Attiwill, 1980) Mean tree age: 50.7 yrs.						
stemwood	77		43	22		13	9
stembark	15		23	50		54	61
branches	6		16	15		19	22
leaves	2		18	13		14	8

TABLE A3.3 BIOMASS AND NUTRIENT MASS OF UNDERSTOREY

FOREST AND UNDERSTOREY TYPES	BIOMASS t/ha	NUTRIENT MASS kg/ha					
		N	P	K	Na	Mg	Ca
E. regnans with *Acacia dealbata*, *A. obliquinervia*, *Pomaderris aspera*, *Correa lawrenciana*, *Prostanthera lasianthos*, *Ziera arborescens*, *Pteridium esculentum*, *Olearia lirata*, *Viola hederacea*, *Geranium solanderi*, *Asperula euryphylla* and *Tetrarrhena juncea* (from Feller, 1980) Forest age: 38 yrs.	53.4	117	12	104	24	24	155
E. regnans with *Bedfordia salicina*, *Pomaderris aspera*, *Prostanthera lasianthos*, *Ziera arborescens* and *Cyathea australis* (from Ashton, 1976) Forest age: 27 yrs.	38.7		1.70				
E. obliqua - *E. dives* with *Acacia oxycedrus*, *A. verticillata*, *Cassinia longifolia*, *Pultenaea juniperina*, *Spyridium parvifolium*, *Blechnum cartilagineum*, *Culcita dubia*, *Pteridium esculentum* and *Tetrarrhena juncea* (from Feller, 1980) Forest age: 38 yrs.	0.9	4	0	7	0	1	1

TABLE A3.4 NUTRIENT CONTENT OF LITTER IN *E. REGNANS* AND *E. OBLIQUA* - *E. DIVES* FORESTS

FOREST TYPE	BIOMASS t/ha	NUTRIENT MASS kg/ha					
		N	P	K	Na	Mg	Ca
E. regnans	65.9	415	12	49	9	46	173
	(from Feller, 1980) Forest age: 38 yrs.						
E. regnans	12.3		2.28				
	(from Ashton, 1976) Forest age: 27 yrs.						
E. obliqua - *E. dives*	32.0	164	12	16	11	28	63
	(from Feller, 1980) Forest age: 38 yrs.						

TABLE A3.5 BIOMASS AND NUTRIENT MASS IN ABOVE GROUND COMPONENTS OF *E. REGNANS* AND *E. OBLIQUA* - *E. DIVES* FORESTS

FOREST TYPE AND COMPONENT PARTS	BIOMASS	NUTRIENT MASS kg/ha					
		N	P	K	Na	Mg	Ca
E. regnans (from Feller, 1980) Forest age: 38 yrs.							
stemwood	490.6 (68)*	113 (14)	9 (18)	898 (63)	64 (44)	78 (33)	157 (15)
bark, branches, leaves	110.3 (15)	169 (21)	17 (34)	387 (27)	50 (34)	90 (38)	537 (53)
understorey	53.4 (7)	117 (14)	12 (24)	104 (7)	24 (16)	24 (10)	155 (15)
litter	65.9 (9)	415 (51)	12 (24)	49 (3)	9 (6)	46 (19)	173 (17)
Total:	720.4	814	50	1438	147	238	1022
E. regnans (from Ashton, 1976) Forest age: 27 yrs.							
stemwood, bark, branches, leaves	792.7 (94)		15.8 (80)				
understorey	38.7 (5)		1.7 (9)				
litter	12.3 (1)		2.3 (11)				
Total:	843.7		19.8				
E. obliqua - *E. dives* (from Feller, 1980) Forest age: 38 yrs.							
E. obliqua							
stemwood	256.6 (63)	216 (37)	6 (21)	28 (22)	36 (32)	20 (20)	79 (24)
bark, branches, leaves	107.1 (26)	187 (32)	10 (35)	70 (56)	64 (57)	46 (46)	171 (53)
E. dives							
total	8.8 (2)	19 (3)	1 (4)	5 (4)	2 (2)	4 (4)	12 (4)
understorey	0.9 (<1)	4 (1)	0	7 (6)	0	1 (1)	1 (<1)
litter	32 (8)	164 (28)	12 (41)	16 (13)	11 (10)	28 (28)	63 (19)
Total:	405.4	590	29	126	113	99	326

*Figures in brackets give the proportion of the total in %

TABLE A3.6 ESTIMATED MASS OF NUTRIENTS IN THE UPPER 120 cm OF SELECTED SOILS IN THE OTWAYS
(Based on data in Pitt, 1931)

PROFILE NO.	PARENT MATERIAL	WEIGHT OF SOIL to 120 cm 10^6 kg/ha	AVAILABLE P Kg/ha	TOTAL P kg/ha	AVAILABLE K kg/ha	EXCHANGEABLE Ca kg/ha	EXCHANGEABLE Mg kg/ha	EXCHANGEABLE K kg/ha
Open Forest IV								
416	Cretaceous sandstone, mudstone and siltstone	12.9	37	980	1440	1100	3080	890
428		12.9	45	1260	1540	1330	1030	1060
739	Tertiary sand, plant remains	11.7	110	500	390	660	210	490
Open Forest III								
736	Cretaceous sandstone, mudstone and siltstone	13.8	80	4800	1610	150	90	2210
748		12.4	35	1200	1440	770	10910	1870
749	Tertiary sand and clay	13.5	30	1320	1190	2660	2040	2360
750	Tertiary sand and clay	13.9	37	1160	1560	2320	6080	1770
782	Lateritized Tertiary sand and clay	13.6	40	1470	770	1780	5430	1090
Open Forest II								
735	Cretaceous sandstone and mudstone	16.1	60	2620	2130	710	25150	4250
746	Tertiary clay and sand	15.6	60	840	660	3180	6090	790
Open Forest I, and Woodland								
426	Tertiary sand	17.7	43	220	750	1810	270	550
608	Tertiary sand	17.5	75	390	740	330	350	230
609	Recent alluvium plant remains	18.0	-	520	1150	60	980	620
740	Tertiary sand	17.6	50	350	620	670	1110	710
742	Tertiary sand	17.6	50	470	300	45	340	220

Note: Nutrient contents of soil profiles, expressed in kg/ha, can only be calculated from soil chemical analyses if bulk density of the soil is known. No bulk density data are available for the Otway soils in question, but reasonable estimates for the purposes in hand have been made and are shown in the following table:

Estimated variation of bulk density (kg/m^3) with vegetation type and depth in the soil profils

Open Forest IV		Open Forest III		Open Forest II		Open Forest I, Woodland	
Soil depth	Bulk density	Soil depth	Bulk density	Soil depth	Bulk density	Soil depth	Bulk density
0-0.3m	700	0-0.2m	700	0-0.2m	900	0-0.2m	1100
0.3-0.6m	1000	0.2-0.4m	1000	0.2-0.4m	1100	0.2-0.4m	1300
0.6-0.9m	1200	0.4-0.8m	1200	0.4-0.8m	1400	0.4-0.8m	1500
0.9-1.2m	1400	0.8-1.2m	1400	0.8-1.2m	1600	0.8-1.2m	1600

These estimates have been made on the basis that:

(i) bulk density tends to increase with depth down the profile, frequently to a value of 1.6 in the subsoil between 1 m and 2 m depth

(ii) bulk densities tend to decrease as the native vegetation becomes increasingly vigorous with a corresponding increase in annual biomass and litter production.

TABLE A3.7 INPUT OF NUTRIENTS FROM WEATHERING OF QUARTZ-BIOTITE-DACITE CALCULATED FROM CATCHMENT NUTRIENT BUDGETS
(Data from Feller, 1981)

NUTRIENT INPUT kg/ha/yr				
P	K	Na	Mg	Ca
1.19	15.90	16.88	7.42	15.97

TABLE A3.8 NUTRIENT INPUT REQUIRED PER ANNUM TO REPLACE NUTRIENTS LOST IF ALL NUTRIENTS IN ABOVE GROUND BIOMASS OF E. REGNANS FOREST (Feller, 1980) LOST FROM SITE AT 38 YEARS
(Data calculated from Table A3.5)

REQUIRED NUTRIENT INPUT kg/ha/yr				
P	K	Na	Mg	Ca
1.32	37.84	3.87	6.26	26.89

Note: Complete loss of nutrients would be an overestimate of nutrient loss in a harvesting/regeneration burn situation as some nutrients would remain after burning.

TABLE A3.9 NUTRIENT INPUT REQUIRED PER ANNUM TO REPLACE NUTRIENTS LOST IF STEMWOOD ONLY REMOVED FROM E. REGNANS FOREST (Feller, 1980) AT AGE 38 YEARS. (Data calculated from Table A3.5)

REQUIRED NUTRIENT INPUT kg/ha/yr				
P	K	Na	Mg	Ca
0.24	23.6	1.68	2.05	19.6

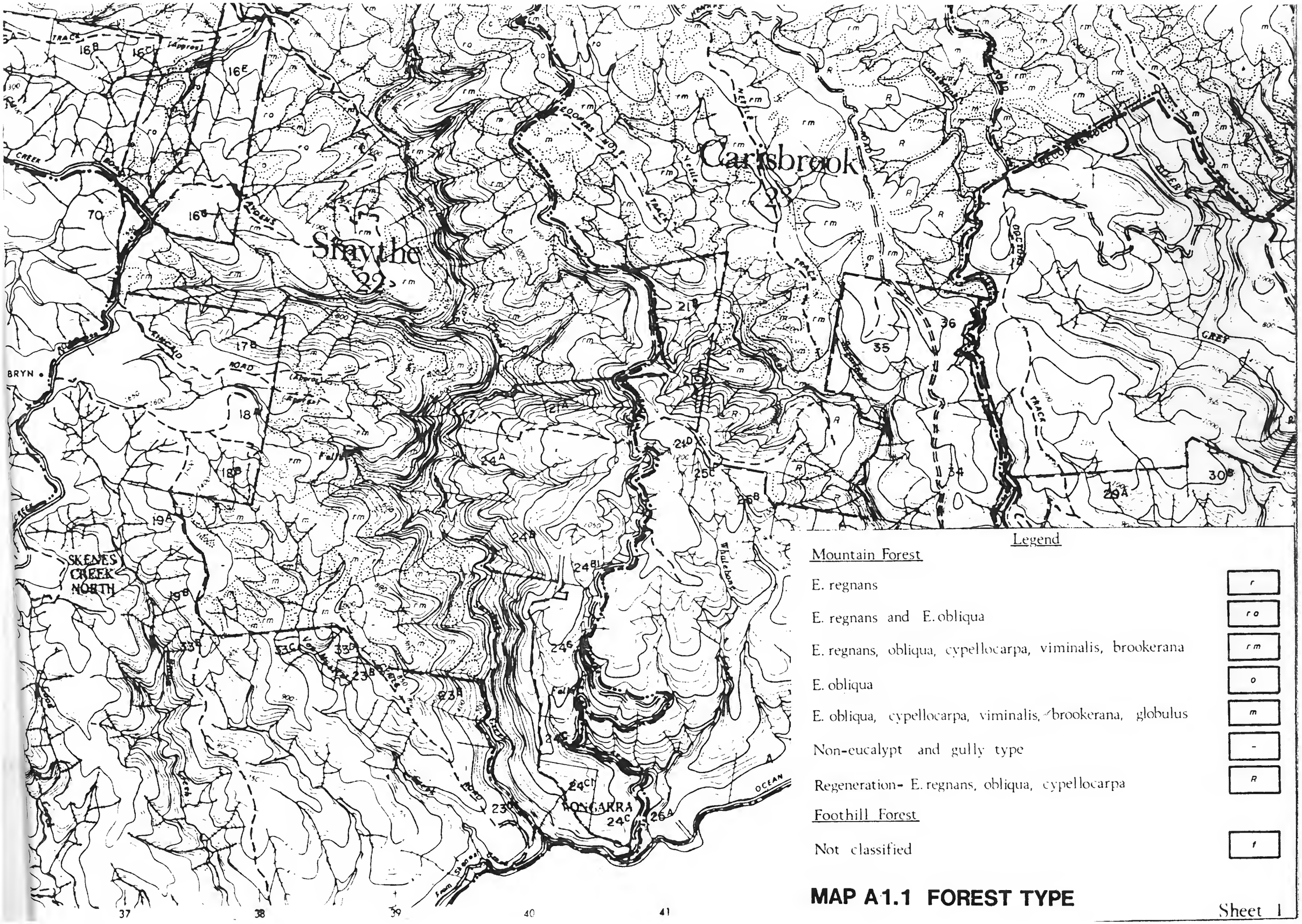
Note: Loss of nutrients calculated from removal of stemwood only would underestimate nutrient removal due to that lost in regeneration burning.

TABLE A3.10 PRECIPITATION INPUT - STREAMFLOW OUTPUT NUTRIENT BUDGET FOR QUARTZ-BIOTITE-DACITE CATCHMENT. (Data from Feller, 1981)

NUTRIENT LOSS kg/ha/yr				
P	K	Na	Mg	Ca
0.05	5.9	20.3	5.3	9.4

TABLE A3.11 NUTRIENT INPUT IN PRECIPITATION. (Data from Charley, 1981)

NUTRIENT INPUT kg/ha/yr				
P	K	Na	Mg	Ca
0.2 - 0.4	0.9 - 9.4		1.1 - 19.4	2.3 - 17.1



Legend

Mountain Forest

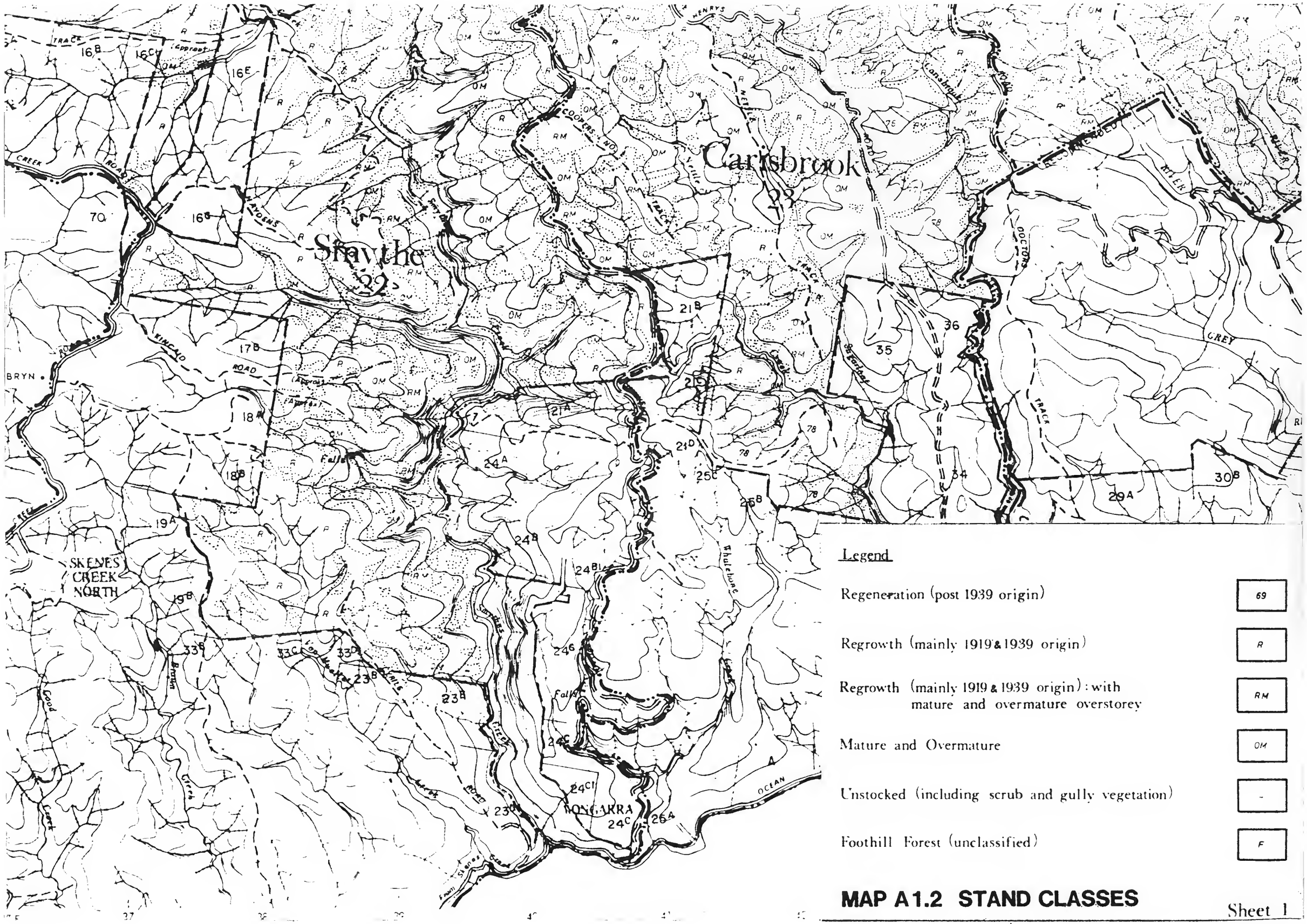
E. regnans	r
E. regnans and E. obliqua	ro
E. regnans, obliqua, cypellocarpa, viminalis, brookerana	rm
E. obliqua	o
E. obliqua, cypellocarpa, viminalis, brookerana, globulus	m
Non-eucalypt and gully type	-
Regeneration- E. regnans, obliqua, cypellocarpa	R

Foothill Forest

Not classified	f

MAP A1.1 FOREST TYPE

Sheet 1



Legend

Regeneration (post 1939 origin)	69
Regrowth (mainly 1919 & 1939 origin)	R
Regrowth (mainly 1919 & 1939 origin): with mature and overmature overstorey	RM
Mature and Overmature	OM
Unstocked (including scrub and gully vegetation)	-
Foothill Forest (unclassified)	F

MAP A1.2 STAND CLASSES

Sheet 1